Survival Estimates for the Passage of Spring-Migrating Juvenile Salmonids through Snake and Columbia River Dams and Reservoirs

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SURVIVAL ESTIMATES FOR THE PASSAGE OF SPRING-MIGRATING JUVENILE SALMONIDS THROUGH SNAKE AND COLUMBIA RIVER DAMS AND RESERVOIRS, 2001

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EXECUTIVE SUMMARY

In 2001, the National Marine Fisheries Service and the University of Washington completed the ninth year of a study to estimate survival and travel time of juvenile salmonids (*Oncorhynchus* spp.) passing through dams and reservoirs on the Snake and Columbia Rivers. All estimates were derived from passive integrated transponder (PIT) -tagged fish. We PIT tagged and released at Lower Granite Dam a total of 17,028 hatchery and 3,550 wild steelhead. In addition, we utilized fish PIT tagged by other agencies at traps and hatcheries upstream of the hydropower system and sites within the hydropower system. PIT-tagged smolts were detected at interrogation facilities at Lower Granite, Little Goose, Lower Monumental, McNary, John Day, and Bonneville Dams and in the PIT-tag detector trawl operated in the Columbia River estuary. Survival estimates were calculated using the Single-Release Model.

Primary research objectives in 2001 were to: 1) estimate reach and project survival and travel time in the Snake and Columbia Rivers throughout the yearling chinook salmon and steelhead migrations; 2) evaluate relationships between survival estimates and migration conditions; and 3) evaluate the survival-estimation models under prevailing conditions.

This report provides reach survival and travel time estimates for 2001 for PIT-tagged yearling chinook salmon and steelhead (hatchery and wild) in the Snake and Columbia Rivers. Results are reported primarily in the form of tables and figures with a minimum of text. More details on methodology and statistical models used are provided in previous reports cited in the text. Results for summer-migrating chinook salmon will be reported separately.

Precise survival and detection probabilities were estimated for most of the 2001 yearling chinook salmon and steelhead migrations. Hatchery and wild fish were combined in some of the analyses. For yearling chinook salmon tagged at or above Lower Granite Dam and subsequently recombined into "release" groups at the dam, 76% were hatchery-reared and 24% were wild. For steelhead, the percentages were 70% hatchery-reared and 30% wild. Estimated survival from the tailrace of Lower Granite Dam to the tailrace of Little Goose Dam averaged 0.939 for yearling chinook salmon and 0.801 for steelhead. From Little Goose Dam tailrace to Lower Monumental Dam tailrace, estimated survival averaged 0.820 and 0.709; from Lower Monumental Dam tailrace to McNary Dam tailrace (including passage through Ice Harbor Dam), estimated survival averaged 0.720 and 0.296; from McNary Dam tailrace to John Day Dam tailrace, estimated survival averaged 0.758 and 0.337; and from John Day Dam tailrace to Bonneville Dam tailrace (including passage through The Dalles Dam), estimated survival averaged 0.645 and 0.753 for yearling chinook salmon and steelhead, respectively.

Combining estimates from the Snake River smolt trap to Lower Granite Dam, from Lower Granite Dam to McNary Dam, and from McNary Dam to Bonneville Dam, estimated survival through the entire hydropower system from the head of Lower Granite reservoir to the tailrace of Bonneville Dam (8 projects) was 0.264 (s.e.: 0.015) for Snake River yearling chinook salmon and 0.038 (s.e.: 0.003) for Snake River steelhead.

For yearling spring chinook salmon released in the Upper Columbia River, estimated survival from point of release to Bonneville Dam tailrace averaged 0.335 (s.e.: 0.084) for fish released from Leavenworth Hatchery and 0.286 (s.e.: 0.072) for those from Winthrop Hatchery. Summer-fall chinook salmon were released as yearlings at Rocky Reach and Rock Island dams, with average estimated survival to Bonneville Dam tailrace of 0.523 (s.e.: 0.050) and 0.487 (s.e.: 0.046), respectively.

Flow volume during the 2001 spring migration period was the lowest recorded during the nine years of this study. Springtime spill was also very limited in 2001. Estimated survival from Lower Granite Dam to the tailrace of Bonneville Dam was the lowest recorded in the past nine years for spring chinook salmon and steelhead. Travel times of fish over this stretch of river were also greatly extended.

During the 2001 migration season, no spill occurred at Snake River Dams. At McNary, John Day, The Dalles, and Bonneville Dams, spill occurred only during one three-week period in the middle part of the migration. We calculated average survival estimates for pre-spill, during-spill, and post-spill blocks for several stocks of chinook salmon and steelhead migrating past these dams. We tested whether survival was higher during the period of spill. Results of these analyses were inconsistent across stocks and sites.

In addition to the main report, we produced three appendices. Appendix I addresses assumption testing for release groups from 1999 through 2001 and potential causes and implications of observed lack of fit of the statistical model. Appendix II addresses the relationship between probability of detection and fish length and the implications of this relationship for survival estimation. Appendix III contains two sets of comments we received from other agencies and our responses to the comments.

CONTENTS

INTRODUCTION

Survival estimates for juvenile chinook salmon (*Oncorhynchus tshawytscha*), sockeye salmon (*O. nerka*), and steelhead (*O. mykiss*) that migrate through reservoirs, hydroelectric projects, and free-flowing sections of the Snake and Columbia Rivers are essential to develop effective strategies for recovering depressed stocks. Many present management strategies were based on estimates of system survival (Raymond 1979, Sims and Ossiander 1981) derived in a river system considerably different from today's (Williams and Matthews 1995). Knowledge of the magnitude, locations, and causes of smolt mortality under present passage conditions, and under conditions projected for the future, are necessary to develop strategies that will optimize smolt survival during migration.

From 1993 through 2000, the National Marine Fisheries Service (NMFS) and the University of Washington (UW) demonstrated the feasibility of using three statistical models to estimate survival of PIT-tagged (Prentice et al. 1990a) juvenile salmonids passing through Snake River dams and reservoirs (Iwamoto et al. 1994; Muir et al. 1995, 1996, 2001a; Smith et al. 1998, 2000a, b; Hockersmith et al. 1999, Zabel et al. 2001). Evaluation of assumptions for these models indicated that all were generally satisfied, and accurate and precise survival estimates were obtained.

In 2001, NMFS and UW completed the ninth year of the study. Research objectives were to: 1) estimate reach and project survival and travel time in the Snake and Columbia Rivers throughout the yearling chinook salmon and steelhead migrations; 2) evaluate relationships between survival estimates and migration conditions; and 3) evaluate the performance of the survival-estimation models under prevailing operational and environmental conditions. River conditions in 2001 were unique compared to previous years of the study. Flow levels during the spring migration were the lowest recorded in the nine years of this study and the lowest since the mid-1970s. Also, very little water was spilled at dams. Results from this year's study will provide valuable information on the survival and travel time of spring-migrating juvenile salmonids during low flow and low spill conditions.

METHODS

Experimental Design

The Single-Release (SR) Model was used to estimate survival for releases of PIT-tagged yearling chinook salmon, sockeye salmon, and steelhead from Snake River Basin hatcheries and traps and from Lower Granite Dam in 2001 (Cormack 1964, Jolly 1965, Seber 1965, Skalski 1998, Skalski et al. 1998, Muir et al. 2001a,b). Iwamoto et al. (1994) presented background information and underlying statistical theory.

During the 2001 migration season, automatic PIT-tag detectors (Prentice et al. 1990a,b,c) were operational in the juvenile bypass systems at Lower Granite (RKm 695), Little Goose (RKm 635), Lower Monumental (RKm 589), McNary (RKm 470), John Day (RKm 347), and Bonneville (Rkm 234) Dams (Fig. 1). A large proportion of PIT-tagged yearling chinook salmon released above Lower Granite Dam were released for the multi-state comparative survival study in 2001, and a little more than half of these fish were transported if detected at Lower Granite and Little Goose dams. However, all other PIT-tagged fish detected at dams were diverted back to the river by slide gates, which allowed for the possibility of detection of a particular fish at more than one downstream site (Marsh et al. 1999). The most downstream site for PIT-tag detections was in the Columbia River estuary between Rkm 65 and 84, where a two-boat trawl towed a PIT-tag detector (Ledgerwood et al. 2000).

For fish released in the Snake River Basin, we used the records of downstream PIT-tag detections in the SR Model to estimate survival from the point of release to Lower Granite Dam tailrace, from Lower Granite Dam tailrace to Little Goose Dam tailrace, from Little Goose Dam tailrace to Lower Monumental Dam tailrace, from Lower Monumental Dam tailrace to McNary Dam tailrace, from McNary Dam tailrace to John Day Dam tailrace, and from John Day Dam tailrace to Bonneville Dam tailrace. For fish released in the upper Columbia River, we estimated survival from the point of release to the tailrace of McNary Dam, from McNary Dam tailrace to John Day Dam tailrace, and from John Day Dam tailrace to Bonneville Dam tailrace.

Lower Granite Dam Tailrace Release Groups

During 2001, wild and hatchery steelhead were collected at the Lower Granite Dam juvenile facility, PIT tagged, and released in approximate proportion to their arrival at Lower Granite Dam throughout the migration season. No yearling chinook salmon were PIT tagged specifically for this study because numbers PIT tagged and released from Snake River Basin hatcheries and traps were sufficient for survival estimation below Lower Granite Dam. For both yearling chinook salmon and steelhead tagged above Lower Granite Dam and subsequently detected at Lower Granite Dam and released to the tailrace, we created daily "release groups" according to the day they were detected at Lower Granite Dam. For steelhead, these groups were then combined with the fish tagged and released each day at Lower Granite Dam. Daily tailrace release groups were then pooled into weekly groups. For these groups leaving Lower Granite Dam, we estimated survival probabilities in reaches between Lower Granite Dam tailrace and McNary Dam tailrace.

McNary Dam Tailrace Release Groups

For both yearling chinook salmon and steelhead tagged at all locations in the Snake River Basin and for fish tagged in the upper Columbia River, we created daily "release groups" of fish detected at McNary Dam and released into the tailrace according to the day of detection at McNary Dam. Daily tailrace release groups were then pooled into weekly groups. For weekly groups leaving McNary Dam, we estimated survival from McNary Dam tailrace to John Day Dam tailrace and from John Day Dam tailrace to Bonneville Dam tailrace.

Survival estimates to Bonneville Dam required the use of detection data from the PIT-tag detector trawl in the Columbia River estuary (Ledgerwood et al. 2000). The trawl was operated 8 hours per day during early and late portions of the migration season, and 16 hours per day during the peak. Survival to the tailrace of Bonneville Dam was estimated for weekly McNary

Dam release groups for which we estimated that at least 90% of the group passed the detector trawl location during the period of 16-hour sampling. Expected passage timing was determined from timing of detection at Bonneville Dam. In 2001, median passage from Bonneville Dam to the trawl location was approximately 2.1 and 2.5 days for yearling chinook salmon and steelhead, respectively.

Snake River Hatchery and Trap Release Groups

In 2001, most hatcheries in the Snake River Basin released PIT-tagged fish as part of research separate from the NMFS/UW survival study. We analyzed data from hatchery releases of PIT-tagged fish to provide estimates of survival and detection probabilities for yearling chinook salmon, sockeye salmon, and steelhead from release to the tailrace of Lower Granite Dam and to points downstream. In the course of characterizing the various hatchery releases, preliminary analyses were performed to determine whether data from multiple release groups could be pooled to increase sample sizes. We neither intended nor attempted to analyze the experiments for which the hatchery groups were released.

We also estimated survival for releases of wild and hatchery PIT-tagged yearling chinook salmon and steelhead from the Salmon (White Bird), Snake, Imnaha, Pahsimeroi, South Fork Salmon, Sawtooth, and Crooked Fork Creek smolt traps to Lower Granite Dam tailrace and points downstream.

Data Analysis

Tagging and detection data were retrieved from the PIT-Tag Information System (PTAGIS) maintained by the Pacific States Marine Fisheries Commission.[1] Data were examined for erroneous records, inconsistencies, and data anomalies. Records were eliminated where appropriate, and all eliminated PIT-tag codes were recorded with the reasons for their elimination. For each remaining PIT-tag code, we constructed a record ("detection history") indicating at which dams the tagged fish was detected and at which it was not detected. Methods for data retrieval, database quality assurance/control, and construction of capture histories were the same as those used in past years (Iwamoto et al. 1994; Muir et al. 1995, 1996; Smith et al. 1998, 2000a, b; Hockersmith et al. 1999, Zabel et al. 2001).

These analyses were conducted with currently available data. It is possible, for a variety of reasons, that the data in the PTAGIS database may be updated in the future. Thus, estimates provided by NMFS or employed in analyses in the future may differ slightly from those contained here.

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[1] Pacific States Marine Fisheries Commission, PIT-Tag Operations Center, 45 SE 82nd Drive, Suite 100, Gladstone, OR 97207.

Tests of Assumptions

As in past years, we evaluated assumptions of the SR Model as applied to the data generated from PIT-tagged juvenile salmonids in the Snake and Columbia Rivers (Burnham et al. 1987).

Survival Estimation

Estimates of survival probabilities under the SR Model are random variables, subject to sampling variability. When true survival probabilities are close to 1.0 and/or when sampling variability is high, it is possible for estimates of survival probabilities to exceed 1.0. For practical purposes, estimates should be considered equal to 1.0 in these cases.

When estimates for a particular river section or passage route were available from more than one release group, the estimates were often combined using a weighted average (Muir et al. 2001a). Weights were inversely proportional to the respective estimated relative variance (coefficient of variation squared). The variance of an estimated survival probability from the SR Model is a function of the estimate itself. Consequently, lower survival estimates tend to have smaller estimated variance. Therefore, we do not use the inverse estimated absolute variance in weighting because lower survival estimates have disproportionate influence, and the resulting weighted mean is biased toward the lower survival estimates.

All survival estimates presented are from point of release (or the tailrace of a dam) to the tailrace of some downstream dam. All survival and detection probability estimates were computed using the statistical computer program SURPH ("Survival with Proportional Hazards") for analyzing release-recapture data, developed at the University of Washington (Skalski et al. 1993, Smith et al. 1994).

Survival Estimates from Point of Release to Bonneville Dam

We estimated survival from point of release to Bonneville Dam for various stocks from both the Snake and upper Columbia Rivers. These estimates were obtained by first estimating weighted average estimated survival over shorter reaches for daily or weekly release groups. The weighting scheme is described above. These average survival estimates were then multiplied to compute the estimated survival probability through the entire reach. We pooled similar fish from different release sites when we re-formed release groups at downstream sites.

For example, for Snake River yearling chinook salmon and steelhead, we multiplied the weighted mean survival estimate from Lower Granite Dam tailrace to McNary Dam tailrace by the weighted mean estimate from McNary Dam tailrace to Bonneville Dam tailrace to obtain an overall estimated mean survival probability from Lower Granite Dam tailrace to Bonneville Dam. Finally, for Snake River fish, we multiplied this result by the survival estimate from fish released from the Snake River trap to Lower Granite Dam to compute estimated survival from the head of Lower Granite Reservoir to the tailrace of Bonneville Dam.

Travel Time and Migration Rate

Travel times were calculated for yearling chinook salmon and steelhead from 1) Lower Granite Dam to Little Goose Dam, 2) Little Goose Dam to Lower Monumental Dam, 3) Lower Monumental Dam to McNary Dam, 4) Lower Granite Dam to McNary Dam, 5) Lower Granite Dam to Bonneville Dam, 6) McNary Dam to John Day Dam, 7) John Day Dam to Bonneville Dam, and 8) McNary Dam to Bonneville Dam. Travel time between any two dams was calculated for each fish detected at both dams as the number of days between last detection at the upstream dam (generally at a PIT-tag detector close enough to the outfall site that fish arrived in the tailrace within minutes after detection) and first detection at the downstream dam. Travel time included the time required to move through the reservoir to the forebay of the downstream dam and any delay associated with residence in the forebay, gatewells, or collection channel prior to detection in the juvenile bypass system.

To facilitate comparisons among the river sections, rate of migration in each section (kilometers per day) was also calculated. Lengths of the river sections are 60 km from Lower Granite Dam to Little Goose Dam, 46 km from Little Goose Dam to Lower Monumental Dam, 119 km from Lower Monumental to McNary Dam, 225 km from Lower Granite to McNary Dam, 461 km from Lower Granite to Bonneville Dam, 123 km from McNary Dam to John Day Dam, 113 km from John Day Dam to Bonneville Dam, and 236 km from McNary Dam to Bonneville Dam. Rate of migration through a river section was calculated as the length of the section (km) divided by the travel time (days) (which included any delay at dams as noted above). For each group, the 20th percentile, median, and 80th percentile travel times and migration rates were determined.

The true complete set of travel times for a release group includes travel times of both detected and nondetected fish. However, using PIT tags, travel times cannot be determined for fish that traverse a river section but are not detected at both ends of the section. Travel time statistics are computed only from travel times for detected fish, which represent a sample of the complete set. Nondetected fish pass dams via turbines and spill, thus, their time to pass a dam is minutes to hours shorter than detected fish passing to the tailrace via the juvenile bypass system.

Comparison of Annual Survival Estimates

We made two comparisons of 2001 results to those obtained in previous years of the NMFS/UW survival study. First, we related survival estimates from specific hatcheries to Lower Granite Dam to migration distance. Second, we compared season-wide survival estimates for specific reaches across years.

Analysis of Effects of Spill on Juvenile Salmonid Survival

River conditions in 2001 were unique compared to previous years of the study (Figures 2, 3, and 4). No spill occurred at Snake River dams. At The Dalles and Bonneville Dams, spill began in the evening of 16 May and continued 24 hours per day through midnight on 15 June, averaging about 30% of the total flow volume. At John Day Dam spill occurred for 12 nighttime hours (centered around midnight) every day, beginning the evening of 25 May and continuing until 15 June (ending at midnight that day). About 30% of the flow volume was spilled during spill hours at John Day Dam. At McNary Dam spill occurred for 12 nighttime hours (centered around midnight) every other day, beginning the evening of 25 May and continuing until 15 June (ending at 6:00 am that day) (Figure 3 gives 24-hour averages). Typically, between 20 and 25% of the flow volume was spilled during spill hours at McNary Dam.

Thus, the spill regime divided the spring migration period into three blocks: at each dam there was an early period with no spill, a middle period during which spill occurred, and a late period with no spill. While these spill regimes were not created for experimental purposes, we investigated effects of spill by examining estimated survival of groups of juvenile salmonids that migrated during different parts of the spring season.

For this purpose, the study reaches were Lower Monumental Dam to McNary Dam and McNary Dam to John Day Dam. (Detection data were not sufficient to include survival analyses in the John Day Dam to Bonneville Dam reach). We analyzed each stock of yearling chinook salmon and steelhead that migrated through these reaches with substantial numbers of PIT-tagged individuals. Each stock was treated separately to evaluate stock-specific effects. The stocks analyzed were: 1) Snake River spring-summer chinook salmon (hatchery and wild combined); 2) Yakima River spring chinook salmon (hatchery and wild combined); 3) upper Columbia River spring chinook salmon from the Leavenworth and Winthrop Hatcheries; 4) upper Columbia River summer-fall chinook salmon raised to yearling stage at Turtle Rock Hatchery; and 5) Snake River steelhead (hatchery and wild combined). In addition, the three spring-summer yearling chinook salmon groups (groups 1-3 above) were pooled for analysis. We omitted the summer-fall chinook salmon from the pooled group, because yearling migration is not a naturally occurring life history for this stock.

For each stock, we created weekly release groups according to the time of passage at the upstream dam of the relevant reach. Dates were selected for the weekly groups such that there were three weekly groups that passed the downstream dam primarily during the spill period. We estimated the survival probability and corresponding standard error for each weekly group.

To investigate effects of spill on survival, we conducted a sequence of hypothesis tests of orthogonal contrasts (Sokal and Rohlf 1981). If the occurrence of spill is the primary determinant of survival, then we would expect: 1) equal survival during the two no-spill periods, and 2) elevated survival during the spill period relative to the no-spill periods. Rejection of either of the two hypotheses constitutes evidence that spill was not the dominant factor determining survival. To test equality of survival in the no-spill periods, we used the first set of hypotheses:

$$H_{10}\text{: } S_{pre-spill} = S_{post-spill}$$

$$H_{1A}\text{: } S_{pre-spill} \neq S_{post-spill}$$

This first test was necessary to determine whether we could combine the no-spill periods for comparison with the spill period second test. If the survival estimates for the no-spill periods were not significantly different, we tested the second null hypothesis to determine whether survival during the spill period was significantly greater than in the no-spill period:

H_{20}: $S_{spill} \leq S_{no-spill}$

H_{2A}: $S_{spill} > S_{no-spill}$

The first hypothesis was tested using the statistic:

$$D_1 = \frac{\tilde{S}_{pre} - \tilde{S}_{post}}{\sqrt{\hat{\text{var}}(\tilde{S}_{pre}) + \hat{\text{var}}(\tilde{S}_{post})}}$$

where $\tilde{S}_i$ is the weighted average of the survival estimates for weekly groups in the period indicated in the subscript, and $\hat{\text{var}}(\tilde{S}_i)$ is the corresponding variance estimate. Under the null hypothesis, D_1 has an approximate Student's *t* distribution with $(n_{pre} + n_{post} - 2)$ degrees of freedom, where n_i is the number of weekly groups in period *i* (Skalski and Robson, 1992).

The test statistic for the second hypothesis compares the average survival estimate for the spill period with the average for the no-spill periods:

$$D_2 = \frac{\tilde{S}_{spill} - \frac{1}{2}(\tilde{S}_{pre} + \tilde{S}_{post})}{\sqrt{\hat{\text{var}}(\tilde{S}_{pre}) + \frac{1}{4}(\hat{\text{var}}(\tilde{S}_{pre}) + \hat{\text{var}}(\tilde{S}_{post}))}}.$$

Under the null hypothesis, D2 has an approximate Student's t distribution with $(n_{spill} + n_{pre} + n_{post} - 3)$ degrees of freedom.

RESULTS

Lower Granite Dam Tagging and Release Information

During 2001, a total of 22,689 yearling chinook salmon (17,310 hatchery origin, 5,379 wild) that were PIT tagged and released upstream of Lower Granite Dam were detected at the dam and returned to the river. Steelhead we released to Lower Granite Dam tailrace combined with those that were released upstream and detected at the dam and returned to the river totaled 50,196 steelhead (34,890 hatchery origin, 15,306 wild). Not all these fish were included in analyses because some passed Lower Granite early or late in the season when sample sizes were too low to produce reliable survival or travel time estimates.

Survival Estimation

Tests of assumptions

Assumption tests indicated more significant violations in 1999 through 2001 than in the earlier years of the study. We present a detailed discussion of the assumption tests, the extent of their violations, possible reasons for the occurrence of the violations, and the implications in Appendices I and II.

Snake River Yearling Chinook Salmon

Survival probabilities were estimated for weekly groups of yearling chinook salmon released in the tailrace at Lower Granite Dam for 9 consecutive weeks from 6 April through 7 June. Survival estimates from Lower Granite Dam tailrace to Little Goose Dam tailrace averaged 0.939 (s.e. 0.006; Table 1). From Little Goose Dam tailrace to Lower Monumental Dam tailrace, estimated survival averaged 0.820 (s.e. 0.009). From Lower Monumental Dam tailrace to McNary Dam tailrace, estimated survival averaged 0.720 (s.e. 0.009). For the combined reach from Lower Granite Dam tailrace to McNary Dam tailrace, survival averaged 0.551 (s.e. 0.011). These survival estimates are weighted for the seasonal outmigration. Estimated detection probabilities remained relatively constant throughout the migration, while estimates of survival decreased considerably for weekly groups passing Lower Granite Dam after 17 May, unlike previous years where weekly survival estimates were generally consistent throughout the season.

We estimated survival probabilities for weekly groups of yearling chinook salmon released in the tailrace at McNary Dam for 6 consecutive weeks from 27 April through 7 June. From McNary Dam tailrace to John Day Dam tailrace, estimated survival increased steadily from 0.575 to 0.831 between late April/early May and the end of May, averaging 0.758 (s.e. 0.024; Table 2). From John Day Dam tailrace to Bonneville Dam tailrace estimated survival was variable, averaging 0.645 (s.e. 0.034). For the combined reach from McNary Dam to Bonneville Dam, estimated survival averaged 0.501 (s.e. 0.027), with little weekly variation.

The product of the average estimates from Lower Granite Dam to McNary Dam and from McNary Dam to Bonneville Dam provided an overall survival estimate from Lower Granite Dam tailrace to Bonneville Dam tailrace of 0.276 (s.e. 0.016). The estimated survival probability through Lower Granite Reservoir and Dam (based on the combined survival of Snake River wild and hatchery chinook salmon releases from the Snake River trap from Table 25) was 0.956 (0.014). Thus, the estimated survival probability through all 8 of the hydrosystem projects encountered by Snake River yearling chinook salmon was 0.264 (0.015).

We also calculated survival probability estimates from Lower Granite Dam tailrace to McNary Dam tailrace for hatchery and wild yearling chinook salmon separately (Tables 3 and 4). Survival estimates for hatchery and wild yearling chinook salmon were similar.

Estimated survival probabilities for daily Lower Granite Dam release groups of yearling chinook salmon (hatchery and wild combined) detected and released to the tailrace of Lower Granite Dam generally decreased through the season in the reaches below Little Goose Dam (Table 5, Fig. 5).

Detection probability estimates for the weekly groups varied little in the Snake River during the season due to the absence of spill, but decreased later in the season at McNary, John Day, and Bonneville Dams when spill began (Tables 6 through 9). Detection probabilities for daily groups of combined hatchery and wild fish varied throughout the season at Little Goose and Lower Monumental Dams, but no temporal trends were apparent (Fig. 6). The daily detection probabilities at McNary Dam followed a general downward trend throughout the season (Fig. 6).

Snake River Steelhead

We estimated survival probabilities for weekly groups of steelhead released in the tailrace of Lower Granite Dam for 9 consecutive weeks from 6 April through 7 June. Survival estimates from Lower Granite Dam tailrace to Little Goose Dam tailrace averaged 0.801 (s.e. 0.010; Table 10). From Little Goose Dam tailrace to Lower Monumental Dam tailrace, estimated survival averaged 0.709 (s.e. 0.008). From Lower Monumental Dam tailrace to McNary Dam tailrace, estimated survival averaged 0.296 (s.e. 0.010). For the combined reach from Lower Granite Dam tailrace to McNary Dam tailrace, there was a general downward trend through time in estimated survival, with a seasonal average of 0.168 (s.e. 0.006).

We estimated survival probabilities for weekly groups of steelhead released in the tailrace of McNary Dam for 4 consecutive weeks from 4 May through 31 May. From McNary Dam tailrace to John Day Dam tailrace, estimated survival averaged 0.337 (s.e. 0.025; Table 11). From John Day Dam tailrace to Bonneville Dam tailrace estimated survival averaged 0.753 (s.e. 0.063). For the combined reach from McNary Dam to Bonneville Dam, estimated survival averaged 0.250 (s.e. 0.016).

The product of the average estimates from Lower Granite Dam to McNary Dam and from McNary Dam to Bonneville Dam provided an overall average survival estimate from Lower

Granite Dam tailrace to Bonneville Dam tailrace of 0.042 (s.e. 0.003). The estimated survival through Lower Granite Reservoir and Dam (based on the combined survival of Snake River wild and hatchery steelhead released from the Snake River trap from Table 25.) was 0.912 (0.007). Thus, the estimated survival probability through all 8 of the hydrosystem projects encountered by Snake River steelhead was 0.038 (0.003)

Survival probabilities were estimated separately for hatchery and wild steelhead from Lower Granite Dam tailrace to McNary Dam tailrace (Tables 12 and 13). Survival estimates for wild and hatchery fish were similar through all reaches.

Estimated survival probabilities for daily release groups of steelhead (hatchery and wild combined) detected and released to or PIT tagged and released to the tailrace of Lower Granite Dam increased early in the season and then tended to decrease as the season progressed (Table 14, Fig. 7). Detection probability estimates for the daily and weekly groups also decreased as the season progressed in the Snake River (without spill) and the Columbia River (with spill later in the season) (Tables 15 through 18, Fig. 8).

Snake River Hatchery Release Groups

Survival probabilities of PIT-tagged hatchery yearling chinook salmon, sockeye salmon, and steelhead from release at Snake River Basin hatcheries to the tailrace of Lower Granite Dam and downstream dams varied among hatcheries (Tables 19 through 21), as did detection probabilities at the detection sites (Tables 22 through 24). Only 5 out of 130 sockeye salmon released at Pettit Lake Creek were detected at Lower Granite Dam, and reliable survival estimates were not possible (Table 21). However, this extremely low level of detection indicated that survival was likely very poor for these fish.

Snake River Smolt Trap Release Groups

Survival probability estimates for juvenile salmonids PIT tagged and released from Snake River Basin smolt traps were generally inversely related to distance of the traps to Lower Granite Dam (Table 25). Estimated detection probabilities were similar among release groups of the same species from different traps (Table 26).

Travel Time and Migration Rate

Travel time estimates for yearling chinook salmon and juvenile steelhead released in the tailraces of Lower Granite and McNary Dams varied throughout the season (Tables 27 through 34, Fig. 9). For both species, migration rates were generally highest in the lower river sections. Migration rates generally increased over time as flow, water temperature, and level of spill increased and, presumably, as fish became more smolted. With the very low flow in 2001, median travel times over all reaches were considerably longer than in the previous 8 years. Snake River spring-summer chinook salmon and steelhead took approximately 10-30 more days to complete the migration from Lower Granite Dam to Bonneville Dam than in previous years (Fig. 9).

Tagging Details for Hatchery Steelhead PIT tagged at Lower Granite Dam

We tagged hatchery (16,981) and wild (3,552) steelhead from 11 April through 9 June at Lower Granite Dam for survival estimates (Tables 35 and 36). Mortality and tag loss were less than 1 percent.

Comparison of Annual Survival Estimates

Estimates of survival from Snake River Basin hatcheries to Lower Granite Dam tailrace were similar or higher to those made in past years. Over the years of the study, we have consistently observed an inverse relationship between the migration distance from the release site to Lower Granite Dam and the estimated survival through that reach (Fig. 10). For 1993-2001 estimates, the negative linear correlation between migration distance and estimated survival was significant ($R^2 = 51.7\%$, $P < 0.0001$).

For yearling chinook salmon, survival was similar to that estimated in previous years for the Lower Granite to Little Goose Dam reach but lower than previously observed in the downstream reaches to McNary Dam (Fig. 11). For steelhead, survival estimates were lower in all Snake River reaches compared to previous years and was particularly low between Lower Monumental and McNary Dams (Fig. 11).

Analysis of Effects of Spill on Juvenile Salmonid Survival

Before providing results of the analysis, we discuss a few limitations. First, the timing of the blocks were not randomly chosen. For spill at McNary and John Day dams, only three treatment periods resulted: early (no spill), middle (spill), and late (no spill). It is therefore difficult to discern spill effects if other confounding temporal effects also exist. Moreover, survival was estimated from an upstream site to a downstream site, and the effects of spill are realized at the downstream site. By necessity, we grouped fish for survival estimation according to the day of detection at the upstream site. But these fish spread out as they migrate downstream; although spill occurred during discrete periods, some fish in a single release group may have experienced spill conditions while others did not. Nevertheless, we believe the analyses can provide some insights into the effects of spill.

Estimates of survival and detection probabilities for weekly groups of chinook salmon migrating between McNary Dam and John Day Dam were similar among the three spring/summer stocks analyzed (Tables 37 and 38, Fig. 12), with the yearling fall chinook exhibiting slightly higher survival. Survival increased gradually through the early part of the season and then dropped drastically for groups released on or after June 7th. This drop coincided with the post-spill period. Detection probabilities dropped somewhat during the spill period from the pre-spill period and then increased substantially after spill ceased (Table 38, Fig. 12). The observed trend of survival increasing gradually through the early part of the season was also observed in previous years for Snake River yearling chinook salmon (Fig. 13, data taken from previous NMFS/UW survival reports).

Survival exhibited variability when release groups were pooled into pre-spill, spill, and post-spill periods (Table 39, Figs. 14 and 15). For Yakima River spring chinook salmon, data were not sufficient to estimate survival for the post-spill period. In five out of the seven cases where the first hypothesis was tested, the null hypothesis was rejected, indicating that survival was different in the pre- and post-spill blocks. This result demonstrates that temporal trends in survival independent of spill patterns are present in the data. When we tested the second hypothesis for three stocks, the null hypothesis was rejected in all three cases indicating that survival was greater during the spill period. Taken as a whole, the inconsistency in results among stocks and sites and the existence of confounding temporal trends combine to offer little support for the overall hypothesis that observed patterns in survival were explained solely by spill. We emphasize, though, that this conclusion does not indicate that spill is not beneficial. Instead, it indicates the existing spill conditions provided an inadequate experimental design to determine the increased survival benefits that may have occurred as a result of spill.

Survival Estimates from Point of Release to Bonneville Dam

Upper Columbia River summer-fall chinook salmon (ocean-type fish raised in hatcheries to the yearling stage) had the highest estimated survival from release to Bonneville Dam: 0.523 (0.050) for fish released at Rock Island Dam, which migrated past six projects, and 0.487 (0.046) for fish released at Rocky Reach Dam, which migrated past seven projects (Table 40). Estimated survival of spring chinook released at hatcheries in the upper Columbia River was somewhat lower: 0.335 (0.084) for fish released at Leavenworth Hatchery, which migrated past six projects, and 0.286 (0.072) for fish released at Winthrop Hatchery, which migrated past eight projects. Fish released at Lower Granite Dam migrated past seven projects. Snake River spring-summer chinook salmon had estimated survival from Lower Granite to Bonneville Dam of 0.276 (0.016), which was similar to that of upper Columbia River spring chinook salmon. Snake River steelhead had estimated survival of 0.042 (0.003) from Lower Granite to Bonneville Dam.

DISCUSSION

The low flow and spill conditions in the Snake and Columbia Rivers that prevailed during the 2001 spring migration season led to low survival for those fish that migrated through the hydrosystem for both Snake River spring-summer chinook salmon and steelhead. For chinook salmon, estimated survival (27.6%) from Lower Granite Dam to Bonneville Dam was substantially lower than survival estimates in the previous 6 years (range 43-59%), which had moderate to high flow and spill levels. Estimated survival in 2001 was similar to that in1993 and 1994 (34 and 31%, respectively), when relatively little spill occurred. Thus, the decrease in spill alone may explain much of the lower survival observed for chinook salmon during the 2001 migration season. However, the estimated system-wide survival for spring chinook salmon in 2001 was substantially higher than the 3% estimated survival from the head of Lower Granite Dam reservoir to the tailrace of Bonneville Dam in 1973, a year with similar flow (Williams et al. 2001). Estimated survival for steelhead in 2001 (4.2%) was considerably lower than any estimates in the previous 8 years and similar to 1973 (1%). We will discuss below some potential causes of the alarmingly low steelhead survival observed in 2001.

Low flow in the Snake River also substantially increased travel times of chinook salmon and steelhead. Median travel time from Lower Granite to Bonneville Dam was approximately 10-30 days longer in 2001 than in recent years. Limited spill in 2001 may have also contributed to longer travel times by increasing delay at the face of dams. Unfortunately, we have no way of distinguishing between spill effects and flow effects on the observed travel times. Extended travel times in 2001 may have contributed to poor survival of juvenile salmonids by lengthening their exposure time to predators and by extending their residence in reservoirs into periods with higher temperatures (Fig. 4) when predators were more active (Vigg and Burley 1991). Protracted juvenile travel times in 2001 may also result in lower smolt-to-adult survival because fish arriving at the estuary later in the season potentially have lower survival during the smolt-to-adult life stage (Zabel and Williams 2002).

Because of the low flow, spill did not occur at Snake River dams during the spring migratory period in 2001. This resulted in higher than usual collection efficiency, with approximately 93% of unmarked chinook salmon and 95% of unmarked steelhead that arrived at Lower Granite Dam subsequently transported from Lower Granite, Little Goose, and Lower Monumental Dams (the percentages are based on a ratio of estimated total PIT-tagged fish to Lower Granite Dam compared to the total number of actual first-time detected fish at the three collector dams). Thus, the ultimate consequences of low flow in 2001 on Snake River stocks will depend almost entirely on the adult return rate of the transported fish. Only a very small percentage of unmarked Snake River fish were subjected to the poor migratory conditions faced by migrants passing downstream though the hydropower system.

The high percentage of fish transported in 2001 had another important consequence: the overall abundance of Snake River juvenile salmonids below Lower Monumental Dam likely was extremely low compared to previous years, and the majority of these fish were PIT-tagged fish that were diverted back into the river. This may have influenced predator/prey dynamics for the PIT-tagged fish and had a large impact on their survival. Another factor potentially affecting predator-prey dynamics in 2001 was the above-average water clarity[2], making salmonid smolts more susceptible to visual predators (Gregory and Levings 1998). Steelhead are particularly susceptible to predation by birds; Collis et al. (2001) found that greater than 15% of the PIT-tagged steelhead entering the Columbia River estuary in1998 were later found on Rice Island, the home of the largest Caspian tern colony in western North America. Crescent Island in the McNary Dam reservoir harbors the second largest Caspian tern colony in western North America, and large populations of gulls and other avian piscivores. In fact, over 5,000 PIT tags from steelhead tagged in 2001 were recovered on Crescent Island (Brad Ryan, NMFS, pers. comm.). Based on preliminary analyses, of all the PIT-tagged steelhead detected at Lower Monumental Dam, 14.2 percent of the tags were later detected on Crescent Island. (Tag-detection percentage is a minimum estimate of mortality due to tern predation, as not all tags taken by birds were detected). Per-project survival for steelhead was substantially lower in the Lower Monumental to McNary Dam reach (two projects, $0.296^{1/2} = 0.544$) than in the Lower Granite to Little Goose Dam reach (0.801) and the Little Goose to Lower Monumental Dam reach (0.709). Also, estimated steelhead survival from McNary to John Day Dam (0.337) was

[2] Data available at http://www.cbr.washington.edu/dart/river.html

substantially lower than estimated per-project survival from John Day to Bonneville Dam (two projects, $0.753^{1/2} = 0.868$). In contrast, 4.1 percent of spring-summer chinook salmon detected at Lower Monumental Dam were subsequently detected on Crescent Island, and the per-project survival estimates for the reaches directly above and below McNary Dam were not substantially different than in other reaches.

Low flow and lack of spill at Snake River dams in 2001 may have contributed to poor steelhead survival in another way. Steelhead have a complex life history and are known to residualize. All steelhead not detected during the 2001 migration season were counted as mortalities in the survival model (fish that died cannot be distinguished from those that residualized). Zaugg and Wagner (1973) found that gill Na^{+}-K^{+} ATPase (an indicator of migratory readiness) and migratory urge declined at water temperatures of 13°C and above. Water temperatures in 2001 were above average, exceeding 13°C by the beginning of May (Fig. 4). Extremely protracted travel times resulted in many steelhead experiencing water temperatures above 13°C for an extended time.

Of the 26,947 wild and hatchery steelhead PIT-tagged and released from the Snake River trap, Salmon River trap, and Lower Granite Dam between in 2001, only 0.15 % were detected during the 2002 spring migration. This is similar to the 1994-2000 yearly average of 0.1% detection rate of juvenile steelhead in the year after their release. Additional steelhead may have migrated during the period that bypass systems and PIT-tag detectors were not operated (winter months), but the numbers were likely small. These detection rates are not large enough to substantially alter survival estimates estimated during the year fish were released.

Results from the 2001 studies provide estimates of survival only during the downstream portion of the migration. We will analyze these data in conjunction with adult returns that will occur over the next three years to determine whether variations in spill, flow, temperature, and passage route produce patterns in smolt-to-adult survival consistent with those observed during the downstream migration phase.

Positive effects of spill have been demonstrated previously on a season-wide basis. Analyses based on early data (1973-1979) suggested that increases in spill had a direct impact on increasing survival (Sims and Ossiander 1981). From our own research studies, we have estimated survival through the hydropower system was lower in 1993 and 1994, when spill occurred only in excess of powerhouse capacity, than it was after spill at all dams was prescribed in the 1995 Biological Opinion (NMFS 1995). Demonstrating in-season effects of spill has been more problematic (Smith et al. 2002). This year was no exception, as it was difficult to distinguish spill effects from underlying temporal trends that existed independent of spill levels. Although survival of yearling chinook salmon passing John Day Dam was higher during the spill period than before, the weekly estimates of survival had an increasing trend before and during spill (Fig. 12), a temporal trend evident in previous years for Snake River yearling chinook salmon (Fig. 13). Thus, if we had applied the same cutoff dates to data from previous years (when no systematic differences in spill patterns existed), we likely would have obtained the same results: higher survival in the later period compared to the earlier period. Also, the results were inconsistent across reaches. For instance, survival of fish passing from Lower Monumental

Dam to John Day Dam was actually higher in the non-spill period at McNary Dam than during the spill period.

The fact that spill benefits were not strongly exhibited this year does not mean they do not exist. As mentioned above, the experimental design that we happened upon this year was by no means ideal. Further, when spill did occur, it was at levels far below those of the previous six years (Fig. 3). Finally, potential positive effects of spill likely go beyond those directly measured as project survival. Smith et al. (2002) found a strong inverse relationship between travel time and spill exposure in the Snake River for both yearling chinook salmon and steelhead. In 2001, with limited or no spill at dams, median travel times were 10 to 30 days longer from Lower Granite to Bonneville Dam for both yearling chinook salmon and steelhead, although this protracted migration was probably also due to low flow. Protracted travel times in 2001 potentially had several detrimental effects on survival of salmon migrating through the hydropower system: extending the migration into periods of high reservoir temperatures, increasing the likelihood of residualization in steelhead, and delaying entry into the estuary. Resolving these issues would require a more rigorous experimental design that included more numerous spill blocks randomly spaced throughout the season and occurring at several dams. If we also wanted to determine response of fish to different levels of spill, we would need to vary the level of spill during blocks. Also, to measure indirect effects, we would have to follow fish to their return as adults. Given the potential complexity of an experiment that would address all these issues, its feasibility would require careful consideration.

RECOMMENDATIONS

1) Coordination of future survival studies with other projects should continue to maximize the data-collection effort and minimize study effects on salmonid resources.

2) To date, little mortality has been found in Lower Granite and most other reservoirs investigated. However, considerable mortality was observed in 2001 in the river reach between Lower Monumental and McNary Dams, particularly for steelhead. The cause of this extensive mortality might be avian predators, and this issues merits further investigation. Estimates of survival from hatcheries to Lower Granite Dam suggest that substantial mortality occurs upstream from the Snake and Clearwater River confluence. Efforts should continue to identify where this mortality occurs.

3) Increasing the number of detection facilities in the Columbia River Basin will improve survival investigations. We recommend installation of detectors and diversion systems at The Dalles and upper-Columbia River dams. The development of flat-plate detector technology in bypass systems and portable streambed flat-plate detectors for use in tributaries would greatly enhance survival estimation capabilities.

4) More effort is needed to understand the assumption violations experienced in 2000 and 2001. We recommend modifying the experimental design to test for effects such as post-bypass mortality.

5) To accurately assess the effects of spill, we recommend a more rigorous experimental design, such as a randomized block design. This can potentially account for confounding temporal variability and eliminate the controversy associated with the 2001 results.

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Table 1. Estimated survival probabilities for Snake River yearling chinook salmon (hatchery and wild combined) detected and released to the tailrace of Lower Granite Dam in 2001. Daily groups pooled weekly. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam.

Date at LGR	Number released	LGR to LGO	LGO to LMO	LMO to MCN	LGR to MCN
06 Apr - 12 Apr	413	0.532 (0.027)	0.846 (0.051)	0.697 (0.070)	0.313 (0.033)
13 Apr - 19 Apr	655	0.936 (0.013)	0.900 (0.027)	0.705 (0.035)	0.594 (0.027)
20 Apr - 26 Apr	2,475	0.956 (0.007)	0.844 (0.013)	0.746 (0.020)	0.602 (0.015)
27 Apr - 03 May	8,834	0.946 (0.005)	0.825 (0.008)	0.740 (0.012)	0.577 (0.009)
04 May - 10 May	3,056	0.880 (0.008)	0.814 (0.015)	0.715 (0.024)	0.512 (0.016)
11 May - 17 May	5,289	0.933 (0.007)	0.754 (0.013)	0.646 (0.018)	0.454 (0.012)
18 May - 24 May	771	0.912 (0.023)	0.603 (0.033)	0.614 (0.065)	0.337 (0.035)
25 May - 31 May	579	0.818 (0.029)	0.640 (0.066)	0.368 (0.061)	0.193 (0.027)
01 Jun - 07 Jun	197	0.772 (0.045)	0.467 (0.119)	0.282 (0.208)	0.102 (0.071)
Weighted mean[a]		**0.939 (0.006)**	**0.820 (0.009)**	**0.720 (0.009)**	**0.551 (0.011)**

[a] Weighted means of the independent estimates for daily groups (31 March - 31 May), with weights inversely proportional to respective estimated relative variances.

Table 2. Estimated survival probabilities for Snake River yearling chinook salmon (hatchery and wild combined) detected and released to the tailrace of McNary Dam in 2001. Daily groups pooled weekly. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: MCN-McNary Dam; JDA-John Day Dam; BON-Bonneville Dam.

Date at MCN	Number released	MCN to JDA	JDA to BON	MCN to BON
27 Apr - 03 May	359	0.575 (0.076)	0.460 (0.177)	0.265 (0.097)
04 May - 10 May	2,642	0.689 (0.032)	0.747 (0.178)	0.515 (0.121)
11 May - 17 May	9,901	0.722 (0.021)	0.733 (0.087)	0.529 (0.061)
18 May - 24 May	18,902	0.789 (0.024)	0.597 (0.048)	0.471 (0.035)
25 May - 31 May	10,353	0.831 (0.034)	0.688 (0.072)	0.572 (0.055)
01 Jun - 07 Jun	4,052	0.795 (0.054)	0.470 (0.106)	0.374 (0.080)
Weighted mean[a]		**0.758 (0.024)**	**0.645 (0.034)**	**0.501 (0.027)**

a Weighted means of the independent estimates for weekly pooled groups (27 April - 07 June), with weights inversely proportional to respective estimated relative variances.

Table 3. Estimated survival probabilities for Snake River hatchery yearling chinook salmon detected and released to the tailrace of Lower Granite Dam in 2001. Daily groups pooled weekly. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam.

Date at LGR	Number released	LGR to LGO	LGO to LMO	LMO to MCN	LGR to MCN
06 Apr - 12 Apr	268	0.504 (0.034)	0.821 (0.065)	0.744 (0.104)	0.308 (0.045)
13 Apr - 19 Apr	459	0.923 (0.016)	0.915 (0.033)	0.681 (0.043)	0.575 (0.033)
20 Apr - 26 Apr	1,668	0.955 (0.009)	0.842 (0.017)	0.732 (0.022)	0.588 (0.017)
27 Apr - 03 May	7,136	0.944 (0.005)	0.846 (0.009)	0.741 (0.013)	0.591 (0.010)
04 May - 10 May	2,363	0.883 (0.010)	0.818 (0.018)	0.717 (0.028)	0.518 (0.019)
11 May - 17 May	4,425	0.932 (0.008)	0.770 (0.015)	0.633 (0.020)	0.455 (0.013)
18 May - 24 May	475	0.903 (0.033)	0.619 (0.048)	0.626 (0.101)	0.350 (0.055)
25 May - 31 May	271	0.791 (0.046)	0.699 (0.123)	0.299 (0.076)	0.165 (0.033)
01 Jun - 07 Jun	49	0.680 (0.077)	0.918 (0.683)	0.267 (0.262)	0.167 (0.112)
Weighted mean[a]		**0.933 (0.012)**	**0.831 (0.014)**	**0.716 (0.016)**	**0.554 (0.022)**

[a] Weighted means of the independent estimates for weekly pooled groups (06 April - 07 June), with weights inversely proportional to respective estimated relative variances.

Table 4. Estimated survival probabilities for Snake River wild yearling chinook salmon detected and released to the tailrace of Lower Granite Dam in 2001. Daily groups pooled weekly. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam.

Date at LGR	Number released	LGR to LGO	LGO to LMO	LMO to MCN	LGR to MCN
06 Apr - 12 Apr	145	0.585 (0.043)	0.883 (0.081)	0.646 (0.094)	0.334 (0.049)
13 Apr - 19 Apr	196	0.966 (0.022)	0.866 (0.045)	0.763 (0.058)	0.638 (0.047)
20 Apr - 26 Apr	807	0.961 (0.011)	0.846 (0.022)	0.790 (0.041)	0.642 (0.033)
27 Apr - 03 May	1,698	0.945 (0.011)	0.744 (0.017)	0.734 (0.026)	0.516 (0.019)
04 May - 10 May	693	0.872 (0.016)	0.803 (0.027)	0.708 (0.044)	0.495 (0.031)
11 May - 17 May	864	0.937 (0.013)	0.692 (0.024)	0.694 (0.040)	0.450 (0.026)
18 May - 24 May	296	0.933 (0.029)	0.588 (0.045)	0.608 (0.078)	0.333 (0.044)
25 May - 31 May	308	0.843 (0.036)	0.601 (0.075)	0.406 (0.086)	0.206 (0.040)
Weighted mean[a]		**0.936 (0.016)**	**0.776 (0.026)**	**0.728 (0.020)**	**0.525 (0.034)**

[a] Weighted means of the independent estimates for weekly pooled groups (06 April - 31 May), with weights inversely proportional to respective estimated relative variances.

Table 5. Estimated survival probabilities for Snake River yearling chinook salmon (hatchery and wild combined) detected and released to the tailrace of Lower Granite Dam in 2001. Daily groups pooled as necessary to calculate estimates. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam.

Date at LGR	Number released	LGR to LGO	LGO to LMO	LMO to MCN	LGR to MCN
31 Mar - 07 Apr	266	0.351 (0.035)	0.610 (0.091)	0.586 (0.116)	0.125 (0.026)
08 Apr - 10 Apr	151	0.433 (0.043)	0.850 (0.084)	0.646 (0.092)	0.238 (0.039)
11 Apr	69	1.014 (0.043)	0.722 (0.086)	0.768 (0.117)	0.562 (0.086)
12 Apr - 14 Apr	139	0.841 (0.036)	1.084 (0.088)	0.601 (0.088)	0.548 (0.068)
15 Apr	53	0.934 (0.051)	0.913 (0.101)	0.757 (0.166)	0.645 (0.133)
16 Apr	74	0.915 (0.039)	0.896 (0.074)	0.781 (0.120)	0.640 (0.096)
17 Apr	66	0.985 (0.030)	0.883 (0.073)	0.686 (0.083)	0.597 (0.068)
18 Apr	162	0.937 (0.025)	0.885 (0.052)	0.727 (0.069)	0.603 (0.054)
19 Apr	228	0.955 (0.022)	0.869 (0.045)	0.714 (0.063)	0.593 (0.049)
20 Apr	172	0.975 (0.022)	0.889 (0.047)	0.748 (0.072)	0.648 (0.060)
21 Apr	285	0.960 (0.017)	0.942 (0.037)	0.655 (0.049)	0.593 (0.041)
22 Apr	267	0.901 (0.025)	0.836 (0.043)	0.804 (0.065)	0.605 (0.048)
23 Apr	225	0.953 (0.020)	0.852 (0.039)	0.984 (0.094)	0.800 (0.076)
24 Apr	325	0.938 (0.020)	0.858 (0.034)	0.765 (0.053)	0.616 (0.042)
25 Apr	409	0.991 (0.020)	0.803 (0.035)	0.722 (0.044)	0.574 (0.034)
26 Apr	792	0.964 (0.013)	0.809 (0.025)	0.709 (0.035)	0.553 (0.026)
27 Apr	838	0.962 (0.014)	0.837 (0.026)	0.760 (0.041)	0.612 (0.031)
28 Apr	1,857	0.955 (0.011)	0.811 (0.018)	0.751 (0.026)	0.582 (0.019)
29 Apr	2,041	0.944 (0.010)	0.819 (0.017)	0.714 (0.022)	0.552 (0.016)
30 Apr	1,730	0.941 (0.011)	0.817 (0.019)	0.742 (0.029)	0.570 (0.022)
01 May	1,147	0.953 (0.011)	0.871 (0.022)	0.736 (0.030)	0.611 (0.023)
02 May	779	0.951 (0.016)	0.817 (0.027)	0.767 (0.041)	0.595 (0.030)
03 May	442	0.882 (0.023)	0.804 (0.036)	0.745 (0.049)	0.529 (0.034)
04 May	584	0.928 (0.017)	0.820 (0.029)	0.780 (0.051)	0.593 (0.039)
05 May	828	0.813 (0.018)	0.834 (0.032)	0.699 (0.048)	0.474 (0.031)
06 May	283	0.902 (0.030)	0.769 (0.054)	0.662 (0.081)	0.459 (0.054)

Table 5. Continued.

Date at LGR	Number released	LGR to LGO	LGO to LMO	LMO to MCN	LGR to MCN
07 May	103	0.956 (0.049)	0.732 (0.083)	0.608 (0.091)	0.425 (0.060)
08 May	226	0.780 (0.030)	0.868 (0.051)	0.674 (0.076)	0.456 (0.051)
09 May	613	0.949 (0.016)	0.764 (0.032)	0.725 (0.054)	0.525 (0.038)
10 May	419	0.869 (0.021)	0.893 (0.045)	0.712 (0.072)	0.552 (0.051)
11 May	348	0.933 (0.021)	0.834 (0.048)	0.674 (0.064)	0.524 (0.045)
12 May	666	0.932 (0.017)	0.753 (0.029)	0.699 (0.042)	0.491 (0.029)
13 May	369	0.895 (0.022)	0.828 (0.042)	0.726 (0.076)	0.538 (0.054)
14 May	1,233	0.951 (0.014)	0.792 (0.027)	0.667 (0.035)	0.502 (0.024)
15 May	1,263	0.933 (0.016)	0.750 (0.027)	0.637 (0.039)	0.446 (0.026)
16 May	920	0.914 (0.022)	0.697 (0.036)	0.572 (0.046)	0.365 (0.027)
17 May	490	1.024 (0.038)	0.633 (0.047)	0.581 (0.071)	0.377 (0.044)
18 May	201	0.918 (0.041)	0.655 (0.059)	0.622 (0.120)	0.374 (0.072)
19 May	167	0.963 (0.054)	0.668 (0.074)	0.739 (0.199)	0.475 (0.126)
20 May - 21May	170	0.986 (0.046)	0.578 (0.071)	0.414 (0.075)	0.236 (0.040)
22 May	84	0.735 (0.066)	0.640 (0.119)	0.654 (0.193)	0.308 (0.088)
23 May	75	0.795 (0.075)	0.439 (0.112)	0.500 (0.224)	0.175 (0.077)
24 May - May 25	152	0.858 (0.054)	0.585 (0.090)	0.574 (0.149)	0.288 (0.070)
26 May	170	0.884 (0.042)	0.623 (0.088)	0.408 (0.094)	0.225 (0.047)
27 May	132	0.876 (0.091)	0.535 (0.145)	0.370 (0.129)	0.173 (0.047)
28 May - 29 May	138	0.730 (0.048)	0.637 (0.142)	0.412 (0.331)	0.192 (0.149)
30 May	28	0.845 (0.240)	0.482 (0.259)	0.444 (0.314)	0.181 (0.123)
31 May	33	0.691 (0.123)	0.595 (0.282)	0.600 (0.445)	0.247 (0.167)
Weighted mean[a]		**0.939 (0.006)**	**0.820 (0.009)**	**0.720 (0.009)**	**0.551 (0.011)**

[a] Weighted means of the independent estimates for daily groups (31 March - 31 May), with weights inversely proportional to respective estimated relative variances.

Table 6. Estimated detection probabilities for Snake River yearling chinook salmon (hatchery and wild combined) detected and released to the tailrace of Lower Granite Dam in 2001. Daily groups pooled weekly. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam.

Date at LGR	Number released	LGO	LMO	MCN
06 Apr - 12 Apr	413	0.806 (0.031)	0.664 (0.048)	0.757 (0.067)
13 Apr - 19 Apr	655	0.826 (0.017)	0.660 (0.026)	0.820 (0.033)
20 Apr - 26 Apr	2,475	0.798 (0.010)	0.681 (0.013)	0.788 (0.019)
27 Apr - 03 May	8,834	0.717 (0.006)	0.638 (0.007)	0.762 (0.011)
04 May - 10 May	3,056	0.798 (0.009)	0.642 (0.014)	0.691 (0.022)
11 May - 17 May	5,289	0.739 (0.008)	0.613 (0.011)	0.682 (0.017)
18 May - 24 May	771	0.744 (0.023)	0.698 (0.035)	0.615 (0.063)
25 May - 31 May	579	0.775 (0.030)	0.548 (0.058)	0.662 (0.087)
01 Jun - 07 Jun	197	0.882 (0.046)	0.659 (0.163)	0.500 (0.354)

Table 7. Estimated detection probabilities for Snake River yearling chinook salmon (hatchery and wild combined) detected and released tothe tailrace of McNary Dam in 2001. Daily groups pooled weekly. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: MCN-McNary Dam; JDA-John Day Dam; BON-Bonneville Dam.

Date at MCN	Number released	JDA	BON
27 Apr - 03 May	359	0.441 (0.065)	0.600 (0.219)
04 May - 10 May	2,642	0.446 (0.023)	0.324 (0.077)
11 May - 17 May	9,901	0.367 (0.012)	0.291 (0.034)
18 May - 24 May	18,902	0.209 (0.007)	0.336 (0.026)
25 May - 31 May	10,353	0.163 (0.008)	0.358 (0.035)
01 Jun - 07 Jun	4,052	0.227 (0.017)	0.394 (0.085)

Table 8. Estimated detection probabilities for Snake River hatchery yearling chinook salmon detected and released to the tailrace of Lower Granite Dam in 2001. Daily groups pooled weekly. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam.

Date at LGR	Number released	LGO	LMO	MCN
06 Apr - 12 Apr	268	0.770 (0.043)	0.668 (0.061)	0.700 (0.095)
13 Apr - 19 Apr	459	0.824 (0.021)	0.662 (0.032)	0.806 (0.041)
20 Apr - 26 Apr	1,668	0.777 (0.012)	0.668 (0.016)	0.814 (0.021)
27 Apr - 03 May	7,136	0.703 (0.007)	0.627 (0.008)	0.758 (0.012)
04 May - 10 May	2,363	0.778 (0.011)	0.618 (0.016)	0.676 (0.025)
11 May - 17 May	4,425	0.712 (0.009)	0.589 (0.013)	0.665 (0.019)
18 May - 24 May	475	0.688 (0.032)	0.647 (0.047)	0.520 (0.084)
25 May - 31 May	271	0.732 (0.047)	0.461 (0.085)	0.800 (0.126)
01 Jun - 07 Jun	49	0.930 (0.069)	0.333 (0.272)	0.500 (0.354)

Table 9. Estimated detection probabilities for Snake River wild yearling chinook salmon detected and released to the tailrace of Lower Granite Dam in 2001. Daily groups pooled weekly. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam.

Date at LGR	Number released	LGO	LMO	MCN
06 Apr - 12 Apr	145	0.860 (0.043)	0.659 (0.077)	0.832 (0.089)
13 Apr - 19 Apr	196	0.829 (0.031)	0.654 (0.046)	0.849 (0.053)
20 Apr - 26 Apr	807	0.840 (0.015)	0.709 (0.023)	0.726 (0.038)
27 Apr - 03 May	1,698	0.781 (0.013)	0.687 (0.017)	0.782 (0.025)
04 May - 10 May	693	0.867 (0.016)	0.723 (0.027)	0.745 (0.043)
11 May - 17 May	864	0.876 (0.015)	0.734 (0.025)	0.777 (0.040)
18 May - 24 May	296	0.826 (0.032)	0.769 (0.049)	0.754 (0.088)
25 May - 31 May	308	0.809 (0.037)	0.624 (0.077)	0.595 (0.111)

Table 10. Estimated survival probabilities for juvenile Snake River steelhead (hatchery and wild combined) detected and released to or PIT tagged and released to the tailrace of Lower Granite Dam in 2001. Daily groups pooled weekly. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam.

Date at LGR	Number released	LGR to LGO	LGO to LMO	LMO to MCN	LGR to MCN
06 Apr - 12 Apr	177	0.685 (0.043)	0.712 (0.100)	0.587 (0.282)	0.286 (0.135)
13 Apr - 19 Apr	431	0.754 (0.025)	0.766 (0.071)	0.311 (0.060)	0.179 (0.032)
20 Apr - 26 Apr	2,644	0.892 (0.009)	0.764 (0.025)	0.323 (0.021)	0.220 (0.013)
27 Apr - 03 May	12,557	0.819 (0.005)	0.727 (0.013)	0.279 (0.011)	0.166 (0.006)
04 May - 10 May	9,668	0.768 (0.006)	0.677 (0.014)	0.309 (0.014)	0.161 (0.007)
11 May - 17 May	10,824	0.750 (0.007)	0.673 (0.019)	0.310 (0.021)	0.157 (0.010)
18 May - 24 May	7,979	0.691 (0.012)	0.710 (0.047)	0.170 (0.023)	0.083 (0.010)
25 May - 31 May	2,930	0.593 (0.028)	0.815 (0.197)	0.079 (0.028)	0.038 (0.010)
01 Jun - 07 Jun	1,447	0.553 (0.036)	0.694 (0.192)	0.148 (0.089)	0.057 (0.030)
Weighted mean[a]		**0.801 (0.010)**	**0.709 (0.008)**	**0.296 (0.010)**	**0.168 (0.006)**

[a] Weighted means of the independent estimates for daily groups (31 Mar - 31 May), with weights inversely proportional to respective estimated relative variances.

Table 11. Estimated survival probabilities for juvenile Snake River steelhead (hatchery and wild combined) detected and released tothe tailrace of McNary Dam in 2001. Daily groups pooled weekly. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: MCN-McNary Dam; JDA-John Day Dam; BON-Bonneville Dam.

Date at MCN	Number released	MCN to JDA	JDA to BON	MCN to BON
04 May - 10 May	181	0.408 (0.063)	0.868 (0.615)	0.354 (0.249)
11 May - 17 May	710	0.311 (0.028)	0.764 (0.213)	0.238 (0.065)
18 May - 24 May	2,034	0.319 (0.037)	0.816 (0.222)	0.260 (0.065)
15 May - 31 May	1,013	0.446 (0.118)	0.498 (0.226)	0.222 (0.082)
Weighted mean[a]		**0.337 (0.025)**	**0.753 (0.063)**	**0.250 (0.016)**

[a] Weighted means of the independent estimates for weekly pooled groups (04 May - 31 May), with weights inversely proportional to respective estimated relative variances.

Table 12. Estimated survival probabilities for juvenile Snake River hatchery steelhead detected and released to or PIT tagged and released to the tailrace of Lower Granite Dam in 2001. Daily groups pooled weekly. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam.

Date at LGR	Number released	LGR to LGO	LGO to LMO	LMO to MCN	LGR to MCN
06 Apr - 12 Apr	158	0.669 (0.047)	0.773 (0.124)	0.522 (0.253)	0.270 (0.126)
13 Apr - 19 Apr	404	0.739 (0.026)	0.759 (0.072)	0.322 (0.066)	0.181 (0.035)
20 Apr - 26 Apr	2,023	0.879 (0.011)	0.760 (0.028)	0.348 (0.025)	0.233 (0.015)
27 Apr - 03 May	7,235	0.783 (0.008)	0.695 (0.017)	0.300 (0.015)	0.164 (0.008)
04 May - 10 May	6,213	0.741 (0.008)	0.656 (0.019)	0.325 (0.020)	0.158 (0.009)
11 May - 17 May	7,461	0.729 (0.011)	0.752 (0.037)	0.250 (0.025)	0.137 (0.012)
18 May - 24 May	6,339	0.695 (0.015)	0.769 (0.070)	0.152 (0.027)	0.081 (0.012)
25 May - 31 May	2,426	0.602 (0.034)	1.123 (0.388)	0.069 (0.035)	0.046 (0.017)
01 Jun - 07 Jun	1,294	0.566 (0.042)	0.640 (0.188)	0.158 (0.096)	0.057 (0.030)
Weighted mean[a]		**0.773 (0.022)**	**0.706 (0.016)**	**0.306 (0.016)**	**0.170 (0.013)**

[a] Weighted means of the independent estimates for weekly pooled groups (06 April - 07 June), with weights inversely proportional to respective estimated relative variances.

Table 13. Estimated survival probabilities for juvenile Snake River wild steelhead detected and released to or PIT tagged and released to the tailrace of Lower Granite Dam in 2001. Daily groups pooled weekly. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam.

Date at LGR	Number released	LGR to LGO	LGO to LMO	LMO to MCN	LGR to MCN
20 Apr - 26 Apr	621	0.932 (0.019)	0.768 (0.055)	0.249 (0.042)	0.178 (0.027)
27 Apr - 03 May	5,322	0.870 (0.007)	0.761 (0.020)	0.253 (0.015)	0.167 (0.009)
04 May - 10 May	3,455	0.817 (0.010)	0.708 (0.020)	0.285 (0.018)	0.165 (0.010)
11 May - 17 May	3,363	0.842 (0.009)	0.638 (0.020)	0.367 (0.032)	0.197 (0.016)
18 May - 24 May	1,640	0.716 (0.020)	0.656 (0.058)	0.202 (0.041)	0.095 (0.017)
25 May - 31 May	504	0.588 (0.051)	0.452 (0.124)	0.107 (0.047)	0.028 (0.010)
Weighted mean[a]		**0.850 (0.019)**	**0.710 (0.023)**	**0.282 (0.021)**	**0.168 (0.010)**

[a] Weighted means of the independent estimates for weekly pooled groups (20 April - 31 May), with weights inversely proportional to respective estimated relative variances.

Table 14. Estimated survival probabilities for juvenile Snake River steelhead (hatchery and wild combined) detected and released to or PIT tagged and released to the tailrace of Lower Granite Dam in 2001. Daily groups pooled as necessary to calculate estimates. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam.

Date at LGR	Number released	LGR to LGO	LGO to LMO	LMO to MCN	LGR to MCN
31 Mar - 11 Apr	81	0.666 (0.064)	0.718 (0.152)	0.670 (0.473)	0.321 (0.223)
12 Apr - 13 Apr	169	0.684 (0.045)	0.739 (0.129)	0.662 (0.507)	0.335 (0.252)
14 Apr - 17 Apr	155	0.805 (0.045)	0.728 (0.127)	0.274 (0.081)	0.160 (0.042)
18 Apr	124	0.719 (0.044)	0.943 (0.148)	0.259 (0.083)	0.175 (0.050)
19 Apr	85	0.804 (0.053)	0.603 (0.086)	0.436 (0.167)	0.211 (0.082)
20 Apr	189	0.867 (0.035)	0.740 (0.085)	0.348 (0.069)	0.223 (0.039)
21 Apr	292	0.828 (0.029)	0.862 (0.082)	0.342 (0.060)	0.244 (0.038)
22 Apr	283	0.875 (0.029)	0.652 (0.055)	0.571 (0.106)	0.326 (0.059)
23 Apr	341	0.880 (0.028)	0.739 (0.074)	0.434 (0.123)	0.283 (0.077)
24 Apr	423	0.899 (0.022)	0.722 (0.058)	0.310 (0.044)	0.201 (0.026)
25 Apr	463	0.954 (0.020)	0.800 (0.057)	0.266 (0.036)	0.203 (0.024)
26 Apr	653	0.889 (0.018)	0.808 (0.065)	0.256 (0.046)	0.184 (0.030)
27 Apr	725	0.900 (0.019)	0.717 (0.046)	0.291 (0.038)	0.188 (0.023)
28 Apr	1,020	0.859 (0.017)	0.709 (0.043)	0.272 (0.034)	0.165 (0.019)
29 Apr	2,086	0.832 (0.012)	0.731 (0.033)	0.227 (0.018)	0.138 (0.010)
30 Apr	1,955	0.812 (0.014)	0.748 (0.033)	0.273 (0.024)	0.166 (0.013)
01 May	2,741	0.798 (0.013)	0.705 (0.027)	0.335 (0.036)	0.189 (0.019)
02 May	2,349	0.795 (0.013)	0.759 (0.032)	0.281 (0.026)	0.170 (0.015)
03 May	1,681	0.814 (0.015)	0.707 (0.032)	0.289 (0.033)	0.166 (0.018)
04 May	1,857	0.801 (0.014)	0.680 (0.028)	0.294 (0.025)	0.160 (0.013)
05 May	1,936	0.780 (0.014)	0.677 (0.029)	0.296 (0.031)	0.156 (0.016)
06 May	1,226	0.771 (0.018)	0.703 (0.041)	0.306 (0.037)	0.166 (0.019)
07 May	482	0.780 (0.026)	0.631 (0.042)	0.376 (0.055)	0.185 (0.027)
08 May	1,328	0.767 (0.017)	0.664 (0.037)	0.295 (0.035)	0.150 (0.017)
09 May	1,574	0.739 (0.015)	0.689 (0.035)	0.357 (0.042)	0.182 (0.020)
10 May	1,265	0.724 (0.018)	0.716 (0.060)	0.263 (0.042)	0.136 (0.019)

Table 14. Continued.

Date at LGR	Number released	LGR to LGO	LGO to LMO	LMO to MCN	LGR to MCN
11 May	1,266	0.711 (0.018)	0.659 (0.047)	0.320 (0.050)	0.150 (0.022)
12 May	1,115	0.752 (0.019)	0.638 (0.052)	0.317 (0.075)	0.152 (0.034)
13 May	1,167	0.741 (0.017)	0.749 (0.056)	0.374 (0.091)	0.208 (0.049)
14 May	1,205	0.781 (0.019)	0.700 (0.046)	0.336 (0.048)	0.184 (0.024)
15 May	2,501	0.772 (0.016)	0.644 (0.041)	0.292 (0.038)	0.145 (0.017)
16 May	2,563	0.771 (0.018)	0.678 (0.047)	0.305 (0.051)	0.159 (0.025)
17 May	1,007	0.733 (0.033)	0.669 (0.081)	0.268 (0.076)	0.131 (0.034)
18 May	2,043	0.763 (0.026)	0.591 (0.054)	0.246 (0.059)	0.111 (0.025)
19 May	1,668	0.695 (0.024)	0.724 (0.096)	0.156 (0.037)	0.079 (0.016)
20 May	1,579	0.657 (0.026)	0.934 (0.201)	0.087 (0.027)	0.053 (0.012)
21 May	567	0.658 (0.047)	0.631 (0.162)	0.200 (0.109)	0.083 (0.040)
22 May	820	0.727 (0.044)	0.770 (0.182)	0.250 (0.153)	0.140 (0.080)
23 May	734	0.618 (0.036)	2.927 (1.958)	0.045 (0.039)	0.081 (0.045)
24 May - 25 May	1,205	0.568 (0.032)	0.798 (0.234)	0.061 (0.023)	0.028 (0.007)
26 May - 31 May	2,293	0.613 (0.036)	0.809 (0.237)	0.114 (0.062)	0.057 (0.026)
Weighted mean[a]		**0.801 (0.010)**	**0.709 (0.008)**	**0.296 (0.010)**	**0.168 (0.006)**

[a] Weighted means of the independent estimates for daily groups (31 March - 31 May), with weights inversely proportional to respective estimated relative variances.

Table 15. Estimated detection probabilities for juvenile Snake River steelhead (hatchery and wild combined) detected and released to or PIT tagged and released to the tailrace of Lower Granite Dam in 2001. Daily groups pooled weekly. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam.

Date at LGR	Number released	LGO	LMO	MCN
06 Apr - 12 Apr	177	0.834 (0.046)	0.649 (0.095)	0.523 (0.249)
13 Apr - 19 Apr	431	0.874 (0.025)	0.649 (0.063)	0.731 (0.117)
20 Apr - 26 Apr	2,644	0.842 (0.010)	0.651 (0.022)	0.781 (0.040)
27 Apr - 03 May	12,557	0.759 (0.006)	0.663 (0.012)	0.768 (0.024)
04 May - 10 May	9,668	0.782 (0.007)	0.675 (0.014)	0.755 (0.028)
11 May - 17 May	10,824	0.731 (0.008)	0.537 (0.016)	0.579 (0.035)
18 May - 24 May	7,979	0.611 (0.012)	0.376 (0.025)	0.542 (0.065)
25 May - 31 May	2,930	0.517 (0.026)	0.226 (0.055)	0.491 (0.129)
01 Jun - 07 Jun	1,447	0.533 (0.037)	0.288 (0.080)	0.408 (0.220)

Table 16. Estimated detection probabilities for juvenile Snake River steelhead (hatchery and wild combined) detected and released tothe tailrace of McNary Dam in 2001. Daily groups pooled weekly. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: MCN-McNary Dam; JDA-John Day Dam; BON-Bonneville Dam.

Date at MCN	Number released	JDA	BON
04 May - 10 May	181	0.515 (0.087)	0.500 (0.354)
11 May - 17 May	710	0.526 (0.051)	0.545 (0.150)
18 May - 24 May	2,034	0.176 (0.025)	0.429 (0.108)
15 May - 31 May	1,013	0.095 (0.029)	0.444 (0.166)

Table 17. Estimated detection probabilities for juvenile Snake River hatchery steelhead detected and released to or PIT tagged and released to the tailrace of Lower Granite Dam in 2001. Daily groups pooled weekly. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam.

Date at LGR	Number released	LGO	LMO	MCN
06 Apr - 12 Apr	158	0.814 (0.051)	0.602 (0.104)	0.526 (0.249)
13 Apr - 19 Apr	404	0.881 (0.025)	0.660 (0.065)	0.711 (0.125)
20 Apr - 26 Apr	2,023	0.848 (0.011)	0.644 (0.025)	0.780 (0.043)
27 Apr - 03 May	7,235	0.736 (0.008)	0.655 (0.016)	0.752 (0.031)
04 May - 10 May	6,213	0.775 (0.009)	0.633 (0.018)	0.710 (0.038)
11 May - 17 May	7,461	0.649 (0.011)	0.409 (0.021)	0.518 (0.045)
18 May - 24 May	6,339	0.579 (0.014)	0.309 (0.028)	0.495 (0.075)
25 May - 31 May	2,426	0.493 (0.030)	0.149 (0.052)	0.393 (0.149)
01 Jun - 07 Jun	1,294	0.520 (0.041)	0.283 (0.083)	0.409 (0.220)

Table 18. Estimated detection probabilities for juvenile Snake River wild steelhead detected and released to or PIT tagged and released to the tailrace of Lower Granite Dam in 2001. Daily groups pooled weekly. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam.

Date at LGR	Number released	LGO	LMO	MCN
20 Apr - 26 Apr	621	0.822 (0.021)	0.681 (0.050)	0.792 (0.107)
27 Apr - 03 May	5,322	0.786 (0.008)	0.673 (0.018)	0.796 (0.037)
04 May - 10 May	3,455	0.792 (0.010)	0.740 (0.020)	0.834 (0.041)
11 May - 17 May	3,363	0.849 (0.010)	0.699 (0.021)	0.684 (0.055)
18 May - 24 May	1,640	0.695 (0.021)	0.549 (0.049)	0.678 (0.119)
25 May - 31 May	504	0.604 (0.055)	0.563 (0.149)	0.750 (0.217)

Table 19. Estimated survival probabilities for PIT-tagged yearling chinook salmon released from snake River Basin hatcheries in 2001. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: Rel-Release site; LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam.

Hatchery	Release site	Number released	Rel to LGR	LGR to LGO	LGO to LMO	LMO to MCN	Rel to MCN
Clearwater	Powell Pond	298	0.664 (0.030)	1.002 (0.043)	0.808 (0.080)	0.602 (0.089)	0.324 (0.043)
Clearwater	Crooked R. Pond	300	0.526 (0.030)	0.946 (0.043)	0.961 (0.087)	0.737 (0.128)	0.352 (0.058)
Clearwater	Lolo Cr.	1,042	0.535 (0.016)	0.952 (0.025)	0.849 (0.042)	0.651 (0.048)	0.282 (0.020)
Clearwater	Newsome Cr.	1,055	0.490 (0.016)	0.959 (0.026)	0.857 (0.045)	0.655 (0.055)	0.263 (0.021)
Dworshak	Dworshak H.	55,142	0.747 (0.002)	0.943 (0.003)	0.838 (0.005)	0.694 (0.007)	0.410 (0.004)
Kooskia	Kooskia H.	749	0.577 (0.019)	0.957 (0.022)	0.830 (0.033)	0.771 (0.051)	0.353 (0.025)
Lookingglass	Imnaha Weir	20,922	0.747 (0.003)	0.962 (0.005)	0.894 (0.008)	0.750 (0.012)	0.481 (0.008)
Lookingglass	Catherine Cr. Pond	20,915	0.519 (0.004)	0.949 (0.008)	0.813 (0.014)	0.663 (0.019)	0.266 (0.007)
Lookingglass	Lostine R. Pond	7,885	0.478 (0.006)	0.950 (0.009)	0.831 (0.016)	0.674 (0.023)	0.255 (0.008)
Lookingglass	Grande Ronde R. Pond	495	0.508 (0.023)	0.944 (0.025)	0.890 (0.053)	0.749 (0.100)	0.320 (0.043)
McCall	Knox Bridge	55,129	0.666 (0.002)	0.934 (0.005)	0.775 (0.008)	0.647 (0.010)	0.312 (0.005)
Pahsimeroi	Pahsimeroi Pond	1,000	0.621 (0.016)	0.974 (0.025)	0.774 (0.049)	0.637 (0.073)	0.298 (0.032)
Rapid River	Rapid River H.	55,091	0.689 (0.002)	0.961 (0.004)	0.855 (0.006)	0.699 (0.008)	0.396 (0.004)
Sawtooth	Sawtooth H.	500	0.524 (0.023)	0.958 (0.025)	0.824 (0.049)	0.632 (0.083)	0.262 (0.035)

Table 20. Estimated survival probabilities for PIT-tagged juvenile steelhead released from Snake River Basin hatcheries in 2001. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: Rel-Release site; LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam.

Hatchery	Release site	Number released	Rel to LGR	LGR to LGO	LGO to LMO	LMO to MCN	Rel to MCN
Clearwater	Lolo Cr.	300	0.473 (0.030)	0.783 (0.061)	0.566 (0.092)	0.353 (0.104)	0.074 (0.021)
Clearwater	S. F. Clearwater	299	0.660 (0.028)	0.863 (0.036)	0.811 (0.083)	NA	NA
Clearwater	Crooked R. Pond	599	0.500 (0.022)	0.751 (0.048)	0.425 (0.049)	0.391 (0.137)	0.062 (0.022)
Clearwater	Red R. Pond	299	0.706 (0.028)	0.722 (0.052)	0.616 (0.100)	0.246 (0.073)	0.077 (0.021)
Dworshak	Clear Cr.	899	0.775 (0.015)	0.782 (0.023)	0.658 (0.050)	0.265 (0.048)	0.106 (0.018)
Dworshak	Dworshak H.	4,205	0.760 (0.007)	0.757 (0.012)	0.746 (0.027)	0.252 (0.019)	0.108 (0.007)
Dworshak	S. F. Clearwater	900	0.793 (0.014)	0.821 (0.023)	0.709 (0.053)	0.271 (0.048)	0.125 (0.021)
Sawtooth	Squaw Creek Pond	300	0.479 (0.033)	1.726 (1.104)	NA	NA	NA

Table 21. Estimated survival probabilities for PIT-tagged juvenile sockeye salmon from Sawtooth Hatchery in 2001. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: Rel-Release site; LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam.

Hatchery	Release site	Number released	Rel to LGR	LGR to LGO	LGO to LMO	LMO to MCN	Rel to MCN
Sawtooth	Alturus L. Cr. (Apr 29)	301	0.370 (0.031)	0.907 (0.119)	0.438 (0.119)	1.286 (1.137)	0.189 (0.164)
Sawtooth	Alturus L. Cr. (May 15)	84	0.393 (0.066)	NA	NA	NA	NA
Sawtooth	Pettit L. Cr. (Apr 29)	143	0.277 (0.054)	0.533 (0.215)	NA	NA	NA
Sawtooth	Pettit L. Cr. (May 15)	130	NA[a]	NA	NA	NA	NA
Sawtooth	Redfish L. Cr.	1,000	0.150 (0.014)	1.292 (0.549)	0.288 (0.174)	0.263 (0.213)	0.015 (0.010)
Sawtooth	Alturus L. Cr. (Apr 29 wild)	164	0.203 (0.039)	0.687 (0.135)	0.525 (0.245)	0.500 (0.382)	0.037 (0.026)

[a] Only 5 fish from this release group were detected at Lower Granite Dam, too few fish to estimate survival.

Table 22. Estimated detection probabilities for PIT-tagged yearling chinook salmon released from Snake River Basin hatcheries in 2001. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam.

Hatchery	Release site	Release number	LGR	LGO	LMO	MCN
Clearwater	Powell Pond	298	0.662 (0.036)	0.693 (0.043)	0.531 (0.060)	0.631 (0.082)
Clearwater	Crooked R. Pond	300	0.793 (0.035)	0.635 (0.047)	0.549 (0.061)	0.532 (0.092)
Clearwater	Lolo Cr.	1,042	0.802 (0.018)	0.643 (0.026)	0.557 (0.033)	0.733 (0.046)
Clearwater	Newsome Cr.	1,055	0.805 (0.019)	0.634 (0.027)	0.573 (0.034)	0.678 (0.051)
Dworshak	Dworshak H.	55,142	0.721 (0.002)	0.784 (0.003)	0.665 (0.005)	0.818 (0.007)
Kooskia	Kooskia H.	749	0.718 (0.023)	0.747 (0.025)	0.693 (0.032)	0.745 (0.047)
Lookingglass	Imnaha Weir	20,922	0.713 (0.004)	0.778 (0.005)	0.629 (0.008)	0.735 (0.011)
Lookingglass	Catherine Cr. Pond	20,915	0.710 (0.005)	0.714 (0.007)	0.590 (0.011)	0.647 (0.017)
Lookingglass	Lostine R. Pond	7,885	0.727 (0.008)	0.722 (0.009)	0.583 (0.013)	0.645 (0.020)
Lookingglass	Grande Ronde R. Pond	495	0.784 (0.027)	0.830 (0.029)	0.611 (0.046)	0.642 (0.084)
McCall	Knox Bridge	55,129	0.787 (0.002)	0.702 (0.004)	0.584 (0.006)	0.680 (0.010)
Pahsimeroi	Pahsimeroi Pond	1,000	0.785 (0.018)	0.718 (0.025)	0.516 (0.036)	0.544 (0.059)
Rapid River	Rapid River H.	55,091	0.776 (0.002)	0.711 (0.004)	0.603 (0.005)	0.730 (0.008)
Sawtooth	Sawtooth H.	500	0.752 (0.028)	0.824 (0.029)	0.729 (0.046)	0.589 (0.078)

Table 23. Estimated detection probabilities for PIT-tagged juvenile steelhead released from Snake River Basin hatcheries in 2001. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam.

Hatchery	Release site	Release number	LGR	LGO	LMO	MCN
Clearwater	Lolo Cr.	300	0.917 (0.028)	0.752 (0.062)	0.721 (0.107)	0.800 (0.179)
Clearwater	S. F. Clearwater	299	0.912 (0.023)	0.803 (0.039)	0.704 (0.075)	NA
Clearwater	Crooked R. Pond	599	0.909 (0.021)	0.719 (0.049)	0.878 (0.066)	0.623 (0.214)
Clearwater	Red R. Pond	299	0.938 (0.021)	0.722 (0.054)	0.684 (0.107)	0.809 (0.173)
Dworshak	Clear Cr.	899	0.909 (0.013)	0.802 (0.024)	0.730 (0.053)	0.709 (0.111)
Dworshak	Dworshak H.	4,205	0.907 (0.006)	0.741 (0.012)	0.673 (0.025)	0.790 (0.044)
Dworshak	S. F. Clearwater	900	0.928 (0.011)	0.779 (0.024)	0.706 (0.052)	0.663 (0.104)
Sawtooth	Squaw Creek Pond	300	0.932 (0.038)	0.111 (0.074)	NA	NA

Table 24. Estimated detection probabilities for PIT-tagged juvenile sockeye salmon from Sawtooth Hatchery in 2001. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam.

Hatchery	Release site	Release number	LGR	LGO	LMO	MCN
Sawtooth	Alturus L. Cr. (Apr 29)	301	0.744 (0.051)	0.625 (0.090)	0.512 (0.133)	0.167 (0.152)
Sawtooth	Alturus L. Cr. (May 15)	84	0.758 (0.106)	NA	NA	NA
Sawtooth	Pettit L. Cr. (Apr 29)	143	0.708 (0.124)	0.500 (0.204)	NA	NA
Sawtooth	Pettit L. Cr. (May 15)	130	NA[a]	NA	NA	NA
Sawtooth	Redfish L. Cr.	1,000	0.778 (0.057)	0.163 (0.074)	0.387 (0.173)	0.143 (0.132)
Sawtooth	Alturus L. Cr. (Apr 29 wild)	164	0.571 (0.108)	0.875 (0.117)	0.500 (0.250)	0.500 (0.354)

[a] Only 5 fish from this release group were detected at Lower Granite Dam, too few fish to estimate detection probability.

Table 25. Estimated survival probabilities for juvenile salmonids released from fish traps in Snake River Basin in 2001. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: Rel-Release; LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam.

Trap	Release dates	Number released	Rel to LGR	LGR to LGO	LGO to LMO	LMO to MCN	Rel to MCN
Hatchery chinook salmon							
Salmon	19 Mar - 01Jun	4,279	0.819 (0.007)	0.942 (0.009)	0.836 (0.015)	0.691 (0.021)	0.445 (0.013)
Snake	27 Apr - 25 May	382	0.956 (0.015)	0.923 (0.027)	0.844 (0.046)	0.747 (0.083)	0.556 (0.059)
Imnaha	23 Mar - 27 Apr	3,008	0.802 (0.008)	0.959 (0.008)	0.900 (0.015)	0.749 (0.022)	0.518 (0.015)
Wild chinook salmon							
Salmon	20 Mar - 08 Jun	1,844	0.875 (0.009)	0.913 (0.012)	0.720 (0.020)	0.632 (0.029)	0.364 (0.017)
Snake	27 Apr - 23 May	30	0.921 (0.058)	0.872 (0.075)	0.850 (0.097)	0.992 (0.202)	0.678 (0.157)
Imnaha	23 Feb - 20 Jun	9,962	0.836 (0.004)	0.944 (0.004)	0.835 (0.008)	0.728 (0.011)	0.480 (0.007)
Pahsimeroi	26 Feb - 31 May	529	0.259 (0.020)	0.778 (0.062)	0.502 (0.073)	0.477 (0.134)	0.048 (0.014)
S. F. Salmon	20 Mar - 14 May	442	0.511 (0.025)	0.877 (0.042)	0.529 (0.067)	0.480 (0.122)	0.114 (0.028)
Sawtooth	21 Mar - 30 May	369	0.643 (0.027)	0.825 (0.042)	0.560 (0.062)	0.441 (0.077)	0.131 (0.023)
Crooked Fork Cr.	20 Mar - 07 May	234	0.525 (0.035)	0.826 (0.055)	0.541 (0.081)	0.405 (0.092)	0.095 (0.022)
Hatchery steelhead							
Salmon	26 Mar - 08 Jun	3,147	0.780 (0.009)	0.676 (0.020)	0.645 (0.050)	0.229 (0.029)	0.078 (0.008)
Snake	27 Apr - 29 May	2,353	0.892 (0.008)	0.691 (0.020)	0.693 (0.058)	0.356 (0.065)	0.152 (0.025)
Imnaha	27 Mar - 25 May	3,297	0.826 (0.008)	0.742 (0.021)	0.683 (0.050)	0.300 (0.044)	0.126 (0.016)

Table 25. Continued

Trap	Release dates	Number released	Rel to LGR	LGR to LGO	LGO to LMO	LMO to MCN	Rel to MCN
Wild steelhead							
Salmon	05 Apr - 08 Jun	478	0.862 (0.020)	0.710 (0.036)	0.634 (0.067)	0.286 (0.062)	0.111 (0.023)
Snake	27 Apr - 29 May	835	0.958 (0.011)	0.818 (0.025)	0.593 (0.037)	0.283 (0.049)	0.131 (0.023)
Imnaha	22 Mar - 25 May	3,572	0.830 (0.007)	0.819 (0.011)	0.719 (0.025)	0.353 (0.031)	0.172 (0.014)
Pahsimeroi	26 Feb - 31 May	429	0.108 (0.016)	0.591 (0.126)	0.597 (0.260)	NA	NA
Sawtooth	14 Apr - 30 May	256	0.170 (0.024)	0.859 (0.163)	0.550 (0.221)	NA	NA
Crooked Fork Cr.	24 Mar - 30 Jun	291	0.482 (0.030)	0.966 (0.040)	0.707 (0.089)	NA	NA
Hatchery sockeye							
Redfish Lake Cr.	24 Apr - 06 Jun	1,389	0.312 (0.014)	0.720 (0.050)	0.530 (0.107)	1.016 (0.946)	0.121 (0.111)
Wild sockeye							
Redfish Lake Cr.	22 Apr - 06 Jun	38	0.553 (0.165)	0.900 (0.718)	NA	NA	NA

Table 26. Estimated detection probabilities for juvenile salmonids released from fish traps in Snake River Basin in 2001. Estimates based on the Single-Release Model. Standard errors in parentheses. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam.

Trap	Release dates	Number released	LGR	LGO	LMO	MCN
Hatchery chinook salmon						
Salmon	19 Mar - 01Jun	4,279	0.782 (0.008)	0.735 (0.009)	0.613 (0.013)	0.692 (0.020)
Snake	27 Apr - 25 May	382	0.794 (0.023)	0.742 (0.029)	0.618 (0.040)	0.633 (0.069)
Imnaha	23 Mar - 27 Apr	3,008	0.719 (0.010)	0.760 (0.010)	0.633 (0.014)	0.741 (0.020)
Wild chinook salmon						
Salmon	20 Mar - 08 Jun	1,844	0.858 (0.009)	0.835 (0.013)	0.694 (0.020)	0.745 (0.030)
Snake	27 Apr - 23 May	30	0.832 (0.077)	0.947 (0.052)	0.687 (0.116)	0.800 (0.179)
Imnaha	23 Feb - 20 Jun	9,962	0.814 (0.004)	0.822 (0.005)	0.676 (0.008)	0.787 (0.011)
Pahsimeroi	26 Feb - 31 May	529	0.861 (0.036)	0.777 (0.062)	0.831 (0.089)	0.575 (0.163)
S. F. Salmon	20 Mar - 14 May	442	0.810 (0.029)	0.839 (0.041)	0.658 (0.081)	0.674 (0.155)
Sawtooth	21 Mar - 30 May	369	0.852 (0.027)	0.809 (0.042)	0.704 (0.072)	0.841 (0.103)
Crooked Fork Cr.	20 Mar - 07 May	234	0.830 (0.039)	0.864 (0.052)	0.775 (0.100)	0.889 (0.105)
Hatchery steelhead						
Salmon	26 Mar - 08 Jun	3,147	0.914 (0.008)	0.626 (0.020)	0.471 (0.037)	0.744 (0.071)
Snake	27 Apr - 29 May	2,353	0.916 (0.008)	0.675 (0.020)	0.425 (0.037)	0.461 (0.078)
Imnaha	27 Mar - 25 May	3,297	0.899 (0.008)	0.578 (0.018)	0.435 (0.032)	0.565 (0.074)

Table 26. Continued

Trap	Release dates	Number released	LGR	LGO	LMO	MCN
Wild steelhead						
Salmon	05 Apr - 08 Jun	478	0.888 (0.020)	0.721 (0.038)	0.689 (0.069)	0.846 (0.142)
Snake	27 Apr - 29 May	835	0.879 (0.014)	0.737 (0.025)	0.796 (0.043)	0.806 (0.124)
Imnaha	22 Mar - 25 May	3,572	0.891 (0.007)	0.800 (0.011)	0.635 (0.023)	0.716 (0.055)
Pahsimeroi	26 Feb - 31 May	429	0.909 (0.061)	0.650 (0.142)	0.667 (0.272)	NA
Sawtooth	14 Apr - 30 May	256	0.894 (0.058)	0.615 (0.135)	0.458 (0.187)	NA
Crooked Fork Cr.	24 Mar - 30 Jun	291	0.864 (0.031)	0.813 (0.045)	0.742 (0.091)	NA
Hatchery sockeye						
Redfish Lake Cr.	24 Apr - 06 Jun	1,389	0.769 (0.027)	0.697 (0.048)	0.482 (0.098)	0.125 (0.117)
Wild sockeye						
Redfish Lake Cr.	22 Apr - 06 Jun	38	0.524 (0.175)	0.333 (0.272)	NA	NA

Table 27. Travel time statistics for Snake River yearling chinook salmon (hatchery and wild combined) detected and released to the tailrace of Lower Granite Dam in 2001. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam; BON-Bonneville Dam; N-Number of fish on which statistics are based; Med.-Median.

	LGR to LGO (days)				LGO to LMO (days)				LMO to MCN (days)			
Date at LGR	N	20%	Med.	80%	N	20%	Med.	80%	N	20%	Med.	80%
06 Apr - 12 Apr	177	10.4	14.9	18.4	92	3.3	5.7	12.0	55	5.3	7.0	11.2
13 Apr - 19 Apr	506	7.1	9.6	12.5	285	2.6	4.0	9.0	195	5.0	6.6	9.2
20 Apr - 26 Apr	1,888	4.4	5.6	8.0	1,076	2.5	5.0	12.4	771	5.0	6.9	10.2
27 Apr - 03 May	5,989	4.3	7.9	12.8	3,138	3.2	5.6	10.2	2,386	4.4	6.0	8.7
04 May - 10 May	2,147	5.9	7.8	10.8	1,115	2.2	4.0	8.4	674	4.1	5.7	8.8
11 May - 17 May	3,644	3.3	4.6	7.4	1,695	2.4	4.2	9.2	945	4.0	5.4	8.5
18 May - 24 May	523	4.8	7.0	11.0	217	2.3	3.5	6.8	108	3.8	5.4	11.8
25 May - 31 May	367	3.4	5.0	12.1	112	2.2	4.2	12.1	39	4.3	6.9	22.7
01 Jun - 07 Jun	134	3.7	6.9	9.4	31	3.1	4.9	16.6	5	9.1	14.2	15.0

	LGR to MCN (days)				LGR to BON (days)			
Date at LGR	N	20%	Med.	80%	N	20%	Med.	80%
06 Apr - 12 Apr	88	23.2	28.5	38.7	25	41.1	51.6	55.0
13 Apr - 19 Apr	299	16.8	22.8	31.4	62	31.8	43.4	47.4
20 Apr - 26 Apr	1,129	15.0	21.0	26.8	232	27.1	36.4	41.4
27 Apr - 03 May	3,772	16.9	20.1	25.2	804	28.5	33.1	37.2
04 May - 10 May	1,050	14.8	18.8	24.7	280	24.6	29.0	33.1
11 May - 17 May	1,558	11.7	15.5	21.1	426	19.0	22.3	28.3
18 May - 24 May	150	11.9	15.8	23.8	24	17.4	20.4	26.6
25 May - 31 May	67	12.2	19.7	30.8	7	19.0	21.5	30.6
01 Jun - 07 Jun	7	22.0	25.4	27.7	0	NA	NA	NA

Table 28. Migration rate statistics for Snake River yearling chinook salmon (hatchery and wild combined) detected and released to the tailrace of Lower Granite Dam in 2001. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam; BON-Bonneville Dam; N-Number of fish observed; Med-Median.

	LGR to LGO (km/day)				LGO to LMO (km/day)				LMO to MCN (km/day)			
Date at LGR	N	20%	Med.	80%	N	20%	Med.	80%	N	20%	Med.	80%
06 Apr - 12 Apr	177	3.3	4.0	5.7	92	3.8	8	13.8	55	10.6	17	22.4
13 Apr - 19 Apr	506	4.8	6.3	8.5	285	5.1	11.5	17.8	195	12.9	18	24
20 Apr - 26 Apr	1,888	7.5	10.6	13.6	1,076	3.7	9.2	18.5	771	11.7	17.3	23.7
27 Apr - 03 May	5,989	4.7	7.6	14.0	3,138	4.5	8.2	14.3	2,386	13.7	19.8	27
04 May - 10 May	2,147	5.5	7.7	10.2	1,115	5.4	11.6	20.4	674	13.5	20.7	29
11 May - 17 May	3,644	8.1	13	18.2	1,695	5.0	10.8	19	945	14	22.2	29.8
18 May - 24 May	523	5.5	8.6	12.4	217	6.8	13	20	108	10.1	22	31.1
25 May - 31 May	367	5.0	12	17.8	112	3.8	10.9	20.5	39	5.2	17.2	27.4
01 Jun - 07 Jun	134	6.3	8.7	16.4	31	2.8	9.3	14.8	5	7.9	8.4	13

	LGR to MCN (km/day)				LGR to BON (km/day)			
Date at LGR	N	20%	Med.	80%	N	20%	Med.	80%
06 Apr - 12 Apr	88	5.8	7.9	9.7	25	8.4	8.9	11.2
13 Apr - 19 Apr	299	7.2	9.9	13.4	62	9.7	10.6	14.5
20 Apr - 26 Apr	1,129	8.4	10.7	15	232	11.1	12.7	17
27 Apr - 03 May	3,772	8.9	11.2	13.3	804	12.4	13.9	16.2
04 May - 10 May	1,050	9.1	12	15.2	280	13.9	15.9	18.8
11 May - 17 May	1,558	10.7	14.5	19.3	426	16.3	20.7	24.2
18 May - 24 May	150	9.5	14.3	18.9	24	17.3	22.6	26.6
25 May - 31 May	67	7.3	11.4	18.5	7	15.1	21.4	24.2
01 Jun - 07 Jun	7	8.1	8.9	10.2	0	NA	NA	NA

Table 29. Travel time statistics for Snake River yearling chinook salmon (hatchery and wild combined) detected and released to the tailrace of McNary Dam in 2001. Abbreviations: MCN-McNary Dam; JDA-John Day Dam; BON-Bonneville Dam; N-Number of fish on which statistics are based; Med.-Median.

	MCN to JDA (days)				JDA to BON (days)				MCN to BON (days)			
Date at MCN	N	20%	Med.	80%	N	20%	Med.	80%	N	20%	Med.	80%
27 Apr - 03 May	91	8.7	14.0	21.9	26	1.9	2.2	3.2	57	12.4	16.4	29.6
04 May - 10 May	813	6.9	10.6	20.2	199	2.0	2.3	2.9	441	9.4	13.6	25.2
11 May - 17 May	2,624	5.0	8.2	16.9	563	2.0	2.3	2.7	1,521	8.1	13.8	19.8
18 May - 24 May	3,111	5.3	9.9	17.1	623	2.0	2.2	2.6	2,993	6.9	11.0	15.5
25 May - 31 May	1,402	4.0	6.6	14.2	339	2.0	2.3	2.7	2,118	5.0	6.2	9.2
01 Jun - 07 Jun	731	3.3	5.2	13.9	137	2.1	2.3	2.7	597	5.0	6.1	9.3

Table 30. Migration rate statistics for Snake River yearling chinook salmon (hatchery and wild combined) detected and released to the tailrace of McNary Dam in 2001. Abbreviations: MCN-McNary Dam; JDA-John Day Dam; BON-Bonneville Dam; N-Number of fish on which statistics are based; Med.-Median.

	MCN to JDA (km/day)				JDA to BON (km/day)				MCN to BON (km/day)			
Date at MCN	N	20%	Med.	80%	N	20%	Med.	80%	N	20%	Med.	80%
27 Apr - 03 May	91	5.6	8.8	14.1	26	34.8	51.1	59.2	57	8.0	14.4	19.1
04 May - 10 May	813	6.1	11.6	17.9	199	38.4	48.9	55.4	441	9.3	17.3	25.2
11 May - 17 May	2,624	7.3	15.1	24.8	563	41.7	48.7	55.9	1,521	11.9	17.1	29.0
18 May - 24 May	3,111	7.2	12.4	23.3	623	42.8	50.4	56.8	2,993	15.2	21.5	34.1
25 May - 31 May	1,402	8.7	18.8	30.8	339	42.5	49.3	55.4	2,118	25.5	37.9	47.0
01 Jun - 07 Jun	731	8.8	23.6	37.5	137	42.2	48.3	54.3	597	25.3	38.9	47.5

Table 31. Travel time statistics for juvenile Snake River steelhead (hatchery and wild combined) detected and released to or PIT tagged and released to the tailrace of Lower Granite Dam in 2001. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam; BON-Bonneville Dam; N-Number of fish on which statistics are based; Med.-Median.

	LGR to LGO (days)				LGO to LMO (days)				LMO to MCN (days)			
Date at LGR	N	20%	Med.	80%	N	20%	Med.	80%	N	20%	Med.	80%
06 Apr - 12 Apr	101	6.3	10.2	15.6	42	5.9	9.1	18.1	14	5.8	8.6	12.0
13 Apr - 19 Apr	284	5.3	8.1	11.3	132	4.5	8.8	15.0	35	5.4	8.9	14.9
20 Apr - 26 Apr	1,985	3.0	4.1	6.4	956	3.2	5.6	13.8	273	5.2	8.0	14.4
27 Apr - 03 May	7,808	2.7	4.7	11.4	3,721	2.8	4.7	9.6	999	4.4	6.0	9.8
04 May - 10 May	5,806	3.9	5.8	9.5	2,631	2.2	3.3	5.9	769	4.0	5.1	7.6
11 May - 17 May	5,937	2.5	3.5	5.7	2,148	1.8	2.7	5.8	513	4.1	5.4	9.6
18 May - 24 May	3,369	3.0	4.6	7.1	900	2.2	3.4	7.2	129	4.2	6.7	11.8
25 May - 31 May	899	2.6	4.6	8.9	168	2.0	3.5	9.9	13	5.9	8.6	10.5
01 Jun - 07 Jun	426	2.6	3.8	6.8	85	2.6	4.2	17.5	9	5.5	7.6	9.0

	LGR to MCN (days)				LGR to BON (days)			
Date at LGR	N	20%	Med.	80%	N	20%	Med.	80%
06 Apr - 12 Apr	23	27.4	36.4	43.0	3	61.4	61.9	68.3
13 Apr - 19 Apr	52	19.2	29.6	37.3	10	38.0	48.8	56.8
20 Apr - 26 Apr	421	15.0	23.9	32.8	86	28.4	36.7	45.2
27 Apr - 03 May	1,522	15.1	18.9	27.7	186	25.0	33.0	40.3
04 May - 10 May	1,126	12.3	15.8	22.4	180	21.5	27.9	34.4
11 May - 17 May	939	9.7	14.5	22.9	146	18.8	24.5	32.4
18 May - 24 May	347	12.3	17.8	28.7	45	20.7	28.5	38.6
25 May - 31 May	53	12.3	21.1	27.0	8	22.5	31.4	36.3
01 Jun - 07 Jun	31	12.6	18.1	21.7	3	20.4	22.4	32.2

Table 32. Migration rate statistics for juvenile Snake River steelhead (hatchery and wild combined) detected and released to or PIT tagged and released to the tailrace of Lower Granite Dam in 2001. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN-McNary Dam; BON-Bonneville Dam; N-Number of fish on which statistics are based; Med.-Median.

	LGR to LGO (km/day)				LGO to LMO (km/day)				LMO to MCN (km/day)			
Date at LGR	N	20%	Med.	80%	N	20%	Med.	80%	N	20%	Med.	80%
06 Apr - 12 Apr	101	3.8	5.9	9.5	42	2.5	5.1	7.8	14	9.9	13.8	20.6
13 Apr - 19 Apr	284	5.3	7.4	11.3	132	3.1	5.2	10.2	35	8.0	13.3	21.9
20 Apr - 26 Apr	1,985	9.4	14.5	20.3	956	3.3	8.2	14.3	273	8.2	14.8	22.8
27 Apr - 03 May	7,808	5.3	12.8	22.0	3,721	4.8	9.8	16.6	999	12.2	19.8	27.0
04 May - 10 May	5,806	6.3	10.3	15.5	2,631	7.8	14.0	20.8	769	15.7	23.3	29.6
11 May - 17 May	5,937	10.5	17.1	24.3	2,148	8.0	17.2	25.8	513	12.4	21.8	29.0
18 May - 24 May	3,369	8.5	13.0	19.7	900	6.4	13.4	21.3	129	10.1	17.8	28.5
25 May - 31 May	899	6.7	13.1	23.0	168	4.6	13.1	22.7	13	11.3	13.8	20.1
01 Jun - 07 Jun	426	8.8	16.0	22.9	85	2.6	10.8	18.0	9	13.3	15.6	21.6

	LGR to MCN (km/day)				LGR to BON (km/day)			
Date at LGR	N	20%	Med.	80%	N	20%	Med.	80%
06 Apr - 12 Apr	23	5.2	6.2	8.2	3	6.8	7.4	7.5
13 Apr - 19 Apr	52	6.0	7.6	11.7	10	8.1	9.4	12.1
20 Apr - 26 Apr	421	6.9	9.4	15.0	86	10.2	12.6	16.2
27 Apr - 03 May	1,522	8.1	11.9	14.9	186	11.4	14.0	18.4
04 May - 10 May	1,126	10.0	14.3	18.2	180	13.4	16.5	21.5
11 May - 17 May	939	9.8	15.5	23.1	146	14.2	18.8	24.5
18 May - 24 May	347	7.8	12.6	18.3	45	11.9	16.2	22.2
25 May - 31 May	53	8.3	10.7	18.4	8	12.7	14.7	20.5
01 Jun - 07 Jun	31	10.4	12.5	17.9	3	14.3	20.6	22.6

Table 33. Travel time statistics for juvenile Snake River steelhead (hatchery and wild combined) detected and released to or PIT tagged and released to the tailrace of McNary Dam in 2001. Abbreviations: MCN-McNary Dam; JDA-John Day Dam; BON-Bonneville Dam; N-Number of fish on which statistics are based; Med.-Median.

	MCN to JDA (days)				JDA to BON (days)				MCN to BON (days)			
Date at MCN	N	20%	Med.	80%	N	20%	Med.	80%	N	20%	Med.	80%
04 May - 10 May	38	5.7	7.4	11.7	17	2.0	2.8	3.0	32	9.2	12.4	21.2
11 May - 17 May	116	4.6	6.0	9.2	48	2.2	2.6	3.0	92	7.7	10.3	18.9
18 May - 24 May	114	4.4	6.3	13.2	40	2.2	2.5	2.8	227	7.4	11.4	16.4
25 May - 31 May	43	4.0	6.7	20.2	10	2.4	2.5	3.0	100	6.4	8.5	13.6

Table 34. Migration rate statistics for juvenile Snake River steelhead (hatchery and wild combined) detected and released to or PIT tagged and released to the tailrace of McNary Dam in 2001. Abbreviations: MCN-McNary Dam; JDA-John Day Dam; BON-Bonneville Dam; N-Number of fish on which statistics are based; Med.-Median.

	MCN to JDA (km/day)				JDA to BON (km/day)				MCN to BON (km/day)			
Date at MCN	N	20%	Med.	80%	N	20%	Med.	80%	N	20%	Med.	80%
04 May - 10 May	38	10.5	16.5	21.6	17	37.2	40.4	55.9	32	11.1	19.0	25.7
11 May - 17 May	116	13.4	20.6	26.9	48	37.8	43.5	52.1	92	12.5	22.8	30.6
18 May - 24 May	114	9.3	19.6	28.1	40	40.5	45.7	50.4	227	14.4	20.7	31.8
25 May - 31 May	43	6.1	18.3	30.7	10	37.5	44.7	47.7	100	17.4	27.8	36.6

Table 35. Number of PIT-tagged hatchery juvenile steelhead released at Lower Granite by day for survival estimates in 2001. Also included are tagging mortalities and lost tags by date.

Release date	Number released	Mortalities	Lost Tags	Release date	Number released	Mortalities	Lost Tags
11 Apr	59	1		09 May	740	1	2
12 Apr	99			10 May	532	1	1
13 Apr	61			11 May	543		3
14 Apr	54			12 May	540	2	2
17 Apr	85			13 May	560		
18 Apr	118			15 May	639		7
19 Apr	75	1		16 May	677	3	1
20 Apr	157			18 May	656	2	2
21 Apr	193			19 May	708	1	4
22 Apr	186			20 May	637		3
23 Apr	254			22 May	368	3	2
24 Apr	241			23 May	404	6	5
25 Apr	243			24 May	368	9	4
26 Apr	219			25 May	351	1	1
27 Apr	215			26 May	371	2	1
28 Apr	209	2	1	30 May	320	5	
29 Apr	230			31 May	308		
01 May	511	15	10	01 Jun	348	2	2
02 May	498		4	02 Jun	325	4	1
03 May	490	1	4	05 Jun	167	3	1
04 May	515		3	06 Jun	57		
05 May	475	1	3	07 Jun	171		1
06 May	533		2	08 Jun	342		3
08 May	691	2	6	09 Jun	341		2

Table 36. Number of PIT-tagged wild juvenile steelhead released at Lower Granite by day for survival estimates in 2001. Also included are tagging mortalities and lost tags by date.

Release date	Number released	Mortalities	Lost Tags	Release date	Number released	Mortalities	Lost Tags
11 Apr	0			09 May	166		
12 Apr	0			10 May	149		
13 Apr	0			11 May	135		2
14 Apr	0			12 May	137	1	
17 Apr	0			13 May	121		
18 Apr	0			15 May	159		
19 Apr	0			16 May	123		
20 Apr	0			18 May	144	1	
21 Apr	43			19 May	90	1	1
22 Apr	26			20 May	164	1	
23 Apr	32			22 May	82		
24 Apr	44			23 May	40		
25 Apr	42			24 May	74		
26 Apr	66	1	1	25 May	98	3	
27 Apr	70			26 May	80	1	
28 Apr	71			30 May	50		
29 Apr	55			31 May	66		
01 May	102	3		01 Jun	23		
02 May	138	1	1	02 Jun	42	3	
03 May	145	1	1	05 Jun	17		
04 May	122		1	06 Jun	1		
05 May	160		1	07 Jun	21		
06 May	105		1	08 Jun	55		
08 May	211			09 Jun	56	1	

Table 37. Estimated survival probabilities for various yearling chinook salmon stocks detected and released to the tailrace of McNary Dam in 2001. Daily groups pooled weekly. Estimates based on the Single-Release Model. Standard errors in parentheses. Release groups that passed John Day primarily during the spill period are in bold. Abbreviations: MCN - McNary Dam; JDA - John Day Dam; SP - spring chinook salmon; S-F - summer-fall chinook salmon.

Date at MCN	Snake River		Upper Columbia R. (SP)		Yakima River		Upper Columbia R. (S-F)[1]	
	Number released	MCN to JDA Survival	Number released	MCN to JDA Survival	Number released	MCN to JDA Survival	Number released	MCN to JDA Survival
12 Apr - Apr 18					76	0.452 (0.089)		
19 Apr - Apr 25					487	0.597 (0.066)	19	0.711 (0.276)
26 Apr - 02 May	205	0.698 (0.175)			845	0.656 (0.058)	1,316	0.872 (0.084)
03 May - 09 May	2,179	0.664 (0.033)	125	0.741 (0.182)	1,693	0.725 (0.046)	6,559	0.861 (0.034)
10 May - 16 May	8,317	0.729 (0.022)	573	0.729 (0.070)	2,253	0.769 (0.041)	11,651	0.834 (0.026)
17 May - 23 May	**18,071**	**0.755 (0.023)**	**1,216**	**0.751 (0.068)**	**2,044**	**0.807 (0.055)**	**19,535**	**0.917 (0.029)**
24 May - 30 May	**11,455**	**0.784 (0.029)**	**2,297**	**0.962 (0.075)**	**1,694**	**0.856 (0.066)**	**19,147**	**0.888 (0.031)**
31 May - 06 Jun	**5,745**	**0.982 (0.063)**	**609**	**0.775 (0.114)**	**1,148**	**0.742 (0.069)**	**6,506**	**0.929 (0.074)**
07 Jun - 13 Jun	1,325	0.661 (0.086)	63	0.370 (0.134)	120	0.850 (0.341)	3,019	0.679 (0.053)
14 Jun - 20 Jun	595	0.360 (0.034)	16	0.469 (0.194)			1,834	0.684 (0.071)
21 Jun - 27 Jun	210	0.200 (0.141)					621	0.667 (0.134)

[1] Dates at McNary Dam for the upper Columbia River summer-fall chinook were three days later than the other groups because they had shorter travel times through the McNary to John Day Dam reach.

Table 38. Estimated detection probabilities at John Day Dam for various yearling chinook salmon stocks detected and released to the tailrace of McNary Dam in 2001. Daily groups pooled weekly. Estimates based on the Single-Release Model. Standard errors in parentheses. Release groups that passed John Day primarily during the spill period are in bold. Abbreviations: JDA - John Day Dam; SP - spring chinook salmon; S-F - summer-fall chinook salmon.

Date at MCN	Snake River		Upper Columbia R. (SP)		Yakima River		Upper Columbia R. (S-F)[1]	
	Number released	JDA Detection	Number released	JDA Detection	Number released	JDA Detection	Number released	JDA Detection
12 Apr - Apr 18					76	0.727 (0.134)		
19 Apr - Apr 25					487	0.440 (0.054)	19	0.667 (0.272)
26 Apr - 02 May	205	0.321 (0.088)			845	0.426 (0.042)	1,316	0.364 (0.038)
03 May - 09 May	2,179	0.450 (0.025)	125	0.421 (0.113)	1,693	0.415 (0.029)	6,559	0.407 (0.017)
10 May - 16 May	8,317	0.393 (0.013)	573	0.440 (0.048)	2,253	0.381 (0.023)	11,651	0.389 (0.013)
17 May - 23 May	**18,071**	**0.231 (0.008)**	**1,216**	**0.299 (0.031)**	**2,044**	**0.290 (0.023)**	**19,535**	**0.228 (0.008)**
24 May - 30 May	**11,455**	**0.177 (0.008)**	**2,297**	**0.203 (0.018)**	**1,694**	**0.234 (0.021)**	**19,147**	**0.232 (0.009)**
31 May - 06 Jun	**5,745**	**0.163 (0.012)**	**609**	**0.276 (0.045)**	**1,148**	**0.323 (0.034)**	**6,506**	**0.216 (0.018)**
07 Jun - 13 Jun	1,325	0.237 (0.034)	63	0.600 (0.219)	120	0.235 (0.103)	3,019	0.401 (0.033)
14 Jun - 20 Jun	595	0.756 (0.064)	16	0.667 (0.272)			1,834	0.398 (0.043)
21 Jun - 27 Jun	210	0.500 (0.354)					621	0.333 (0.070)

[1]Dates at McNary Dam for the upper Columbia River summer-fall chinook were three days later than the other groups because they had shorter travel times through the McNary to John Day Dam reach.

Table 39. Weighted average survival estimates (with standard errors in parentheses) by spill block for various salmonid stocks in 2001. Details of the hypothesis testing are provided in the text. Abbreviations: MCN - McNary Dam; JDA - John Day Dam; H1 - hypothesis 1; H2 - hypothesis 2; SP - spring chinook salmon; S-F - summer-fall chinook salmon.

		Survival Estimates (Standard Errors)			*P*-values		
Stock	Reach	Pre-Spill	Spill	Post-Spill	H1	H2	Conclusion
Snake R. Chinook	MCN-JDA	0.711 (0.020)	0.792 (0.050)	0.461 (0.103)	0.075	0.015	spill greater than non-spill
U. Columbia Chinook (SP)	MCN-JDA	0.731 (0.004)	0.859 (0.072)	0.413 (0.049)	0.023		non-spill periods different
Yakima R. Chinook	MCN-JDA	0.712 (0.036)	0.808 (0.030)	NA	NA	0.043	spill greater than non-spill
Pooled Yearling Chinook	MCN-JDA	0.712 (0.022)	0.800 (0.037)	0.471 (0.102)	0.061	0.006	spill greater than non-spill
U. Columbia Chinook (S-F)	MCN-JDA	0.846 (0.010)	0.906 (0.011)	0.680 (0.003)	0.000		non-spill periods different
Snake R. Steelhead	MCN-JDA	0.325 (0.036)	0.373 (0.071)	0.152 (0.034)	0.040		non-spill periods different
Snake R. Chinook	LMO-MCN	0.736 (0.010)	0.674 (0.047)	0.218 (0.015)	0.000		non-spill periods different
Snake R. Steelhead	LMO-MCN	0.315 (0.018)	0.244 (0.030)	0.060 (0.007)	0.000		non-spill periods different

Table 40. Average survival estimates (with standard errors in parentheses) from point of release to Bonneville Dam tailrace for various spring-migrating salmonid stocks. For each reach, the survival estimate represents a weighted average of daily or weekly estimates (some of which are presented in other tables in this document). In some cases, fish from separate release sites were pooled at downstream sites so survival estimates were identical. Abbreviations: RLS-release site; MCN-McNary Dam; JDA-John Day Dam; BON-Bonneville Dam; SP - spring chinook salmon; SP-SU - spring-summer; S-F - summer-fall chinook salmon.

Stock	Release Location	Survival Estimates (standard errors)			
		RLS - MCN	MCN - JDA	JDA - BON	RLS - BON
Snake R. Chinook (SP-SU)	Lower Granite Dam	0.551 (0.011)	0.758 (0.024)	0.645 (0.034)	0.276 (0.016)
U. Columbia Chinook (SP)	Leavenworth H.	0.500 (0.008)	0.812 (0.051)	0.788 (0.264)	0.335 (0.084)
U. Columbia Chinook (SP)	Winthrop H.	0.427 (0.009)	0.812 (0.051)	0.788 (0.264)	0.286 (0.072)
U. Columbia Chinook (S-F)	Rock Island Dam	0.747 (0.010)	0.863 (0.018)	0.787 (0.067)	0.523 (0.050)
U. Columbia Chinook (S-F)	Rocky Reach Dam	0.695 (0.009)	0.863 (0.018)	0.787 (0.067)	0.487 (0.046)
Yakima R. Chinook	Several Locations	NA[1]	0.743 (0.029)	0.607 (0.080)	NA
Snake R. Steelhead	Lower Granite Dam	0.168 (0.006)	0.337 (0.025)	0.753 (0.063)	0.042 (0.003)

[1] Fish were released at numerous locations in the Yakima River basin. Single point of release to McNary survival estimate not possible.

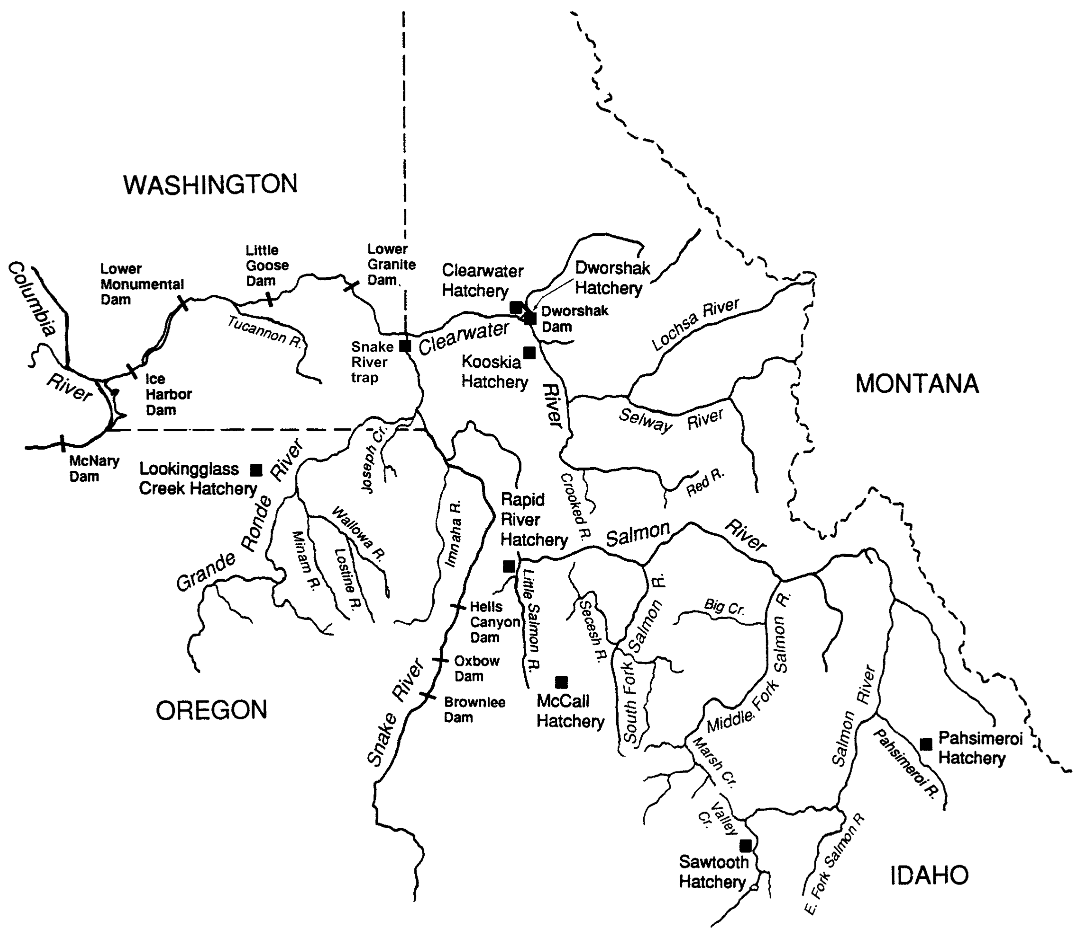


Figure 1. Study area showing release and detection sites on the Snake River.

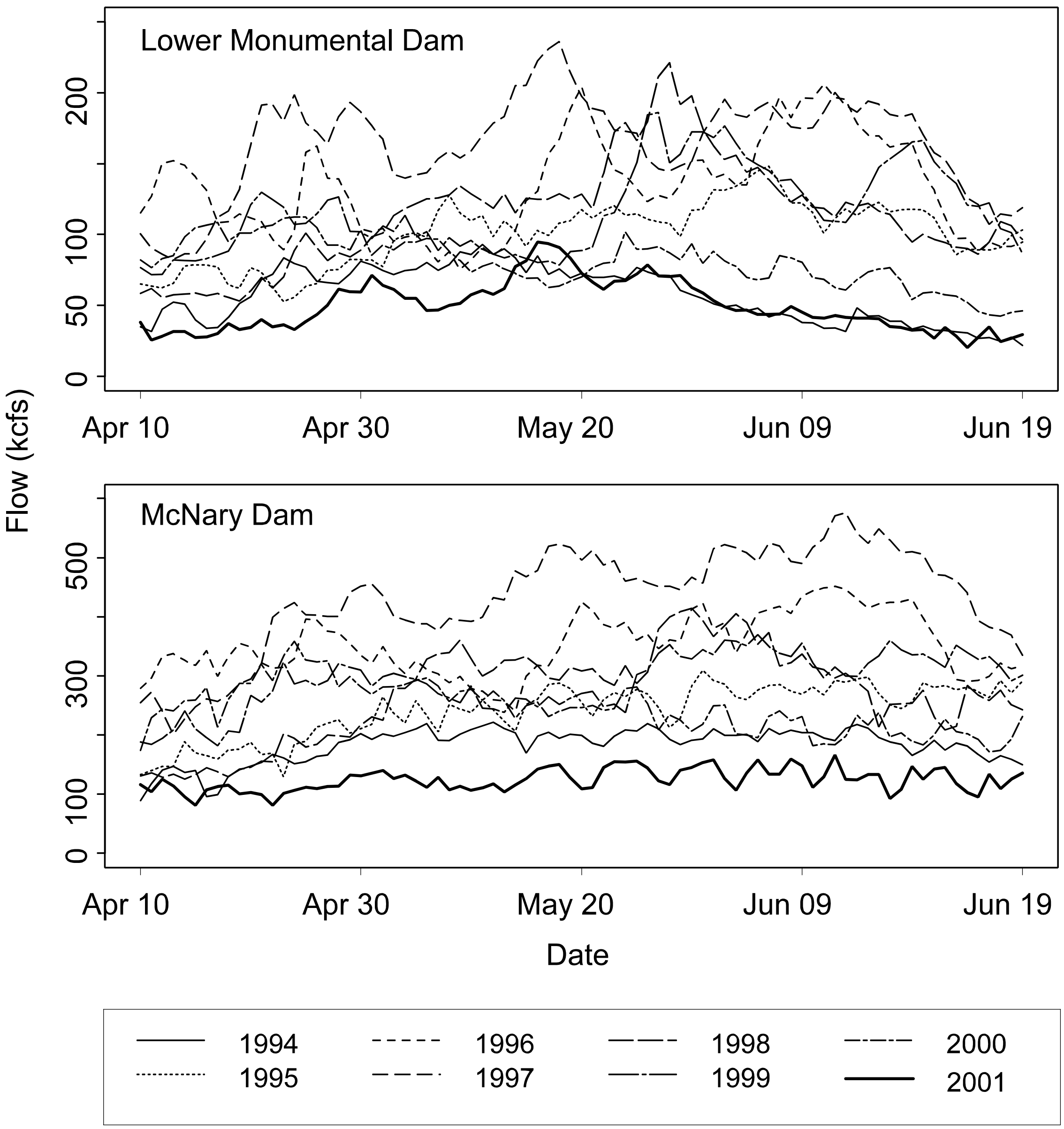


Figure 2. Daily flow rate (kcfs) at Lower Monumental and McNary Dams, 1994-2001.

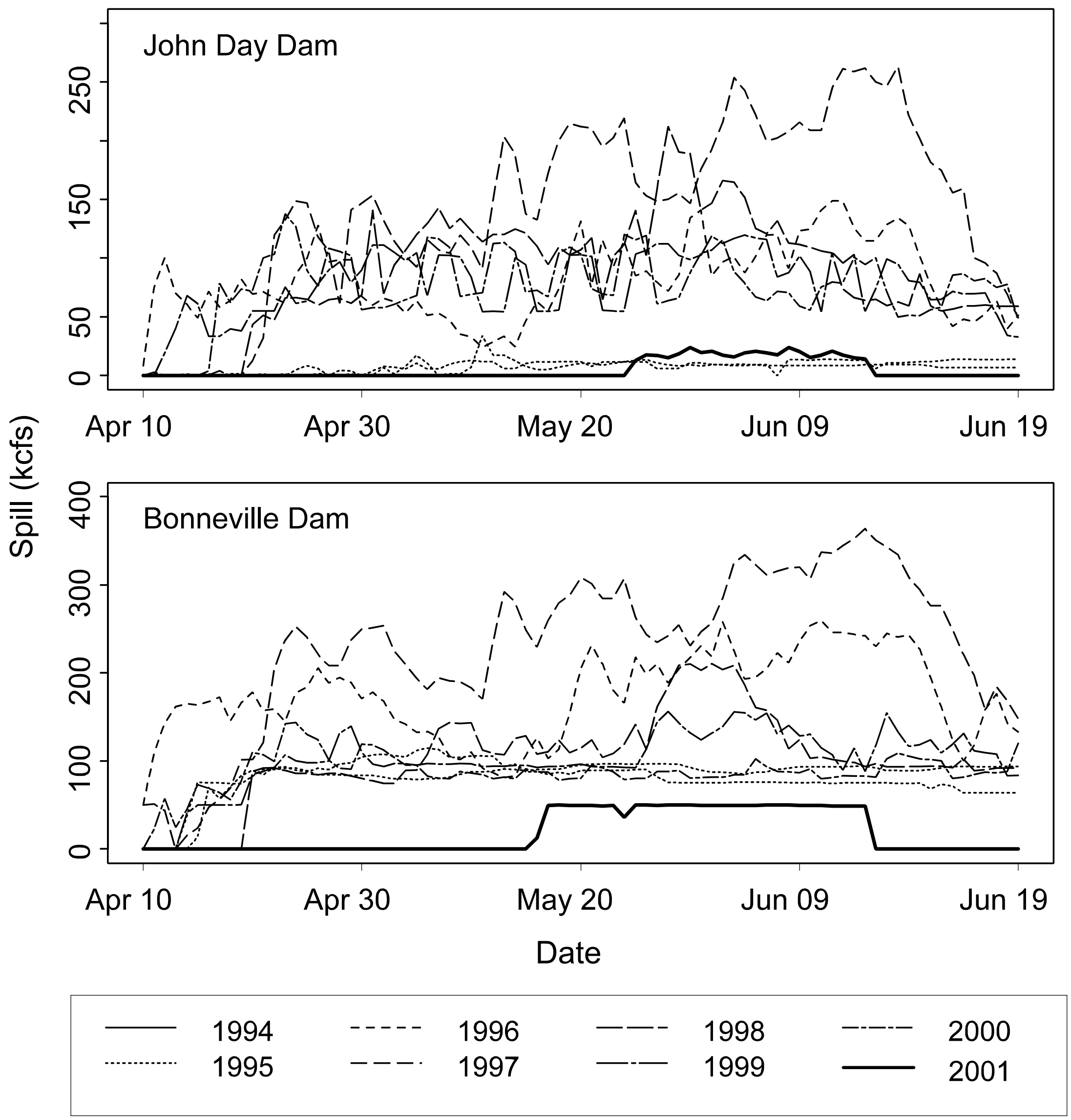


Figure 3. Daily spill rate (kcfs) at John Day and Bonneville Dams, 1994-2001. Details of 2001 spill: patterns at McNary Dam were similar to those at John Day Dam; patterns at The Dalles Dam were similar to those at Bonneville Dam; no spill occurred at Snake River dams during the spring migration period.

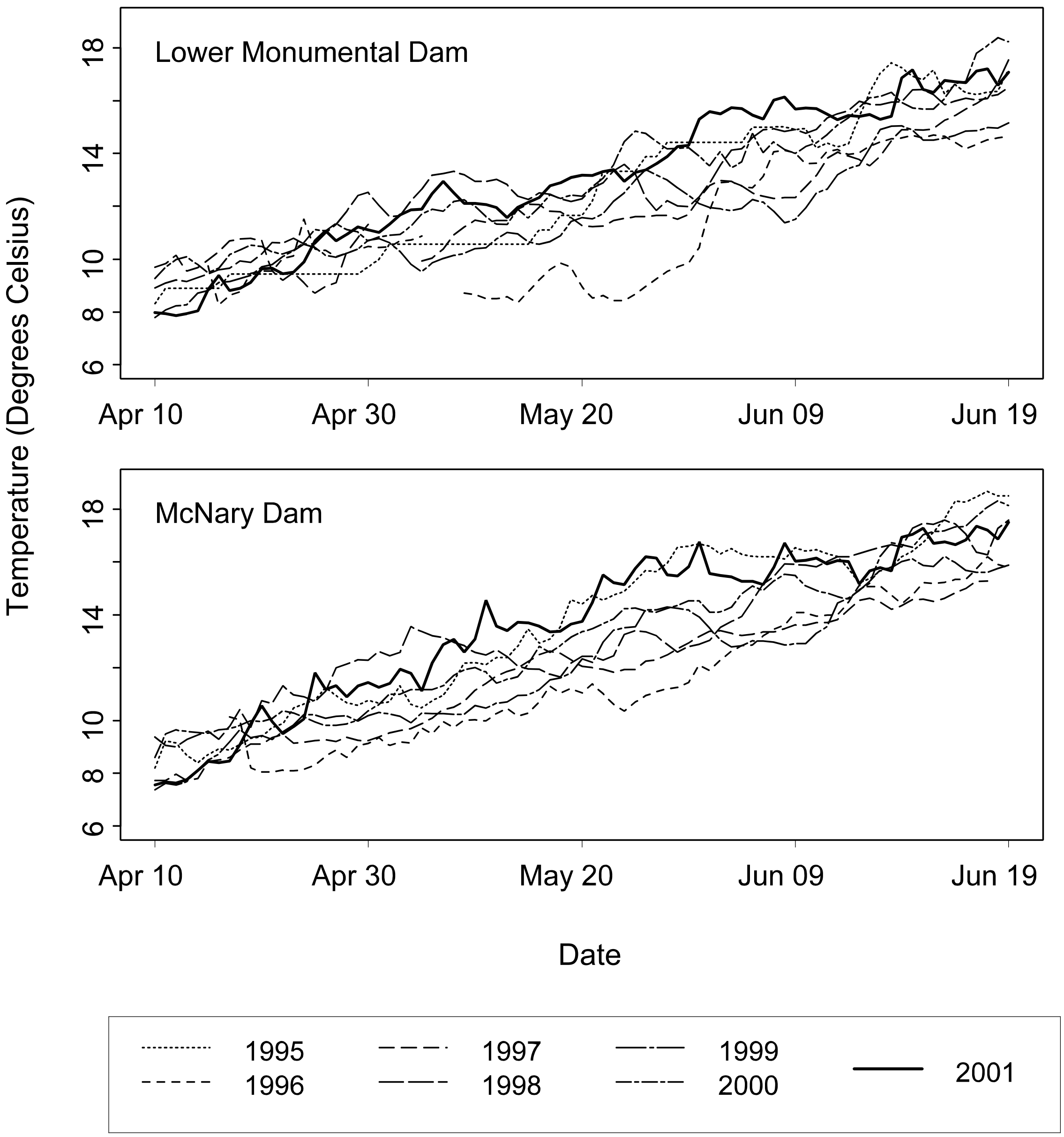


Figure 4. Daily temperature (degrees Celsius) at Lower Monumental and McNary Dams, 1995-2001.

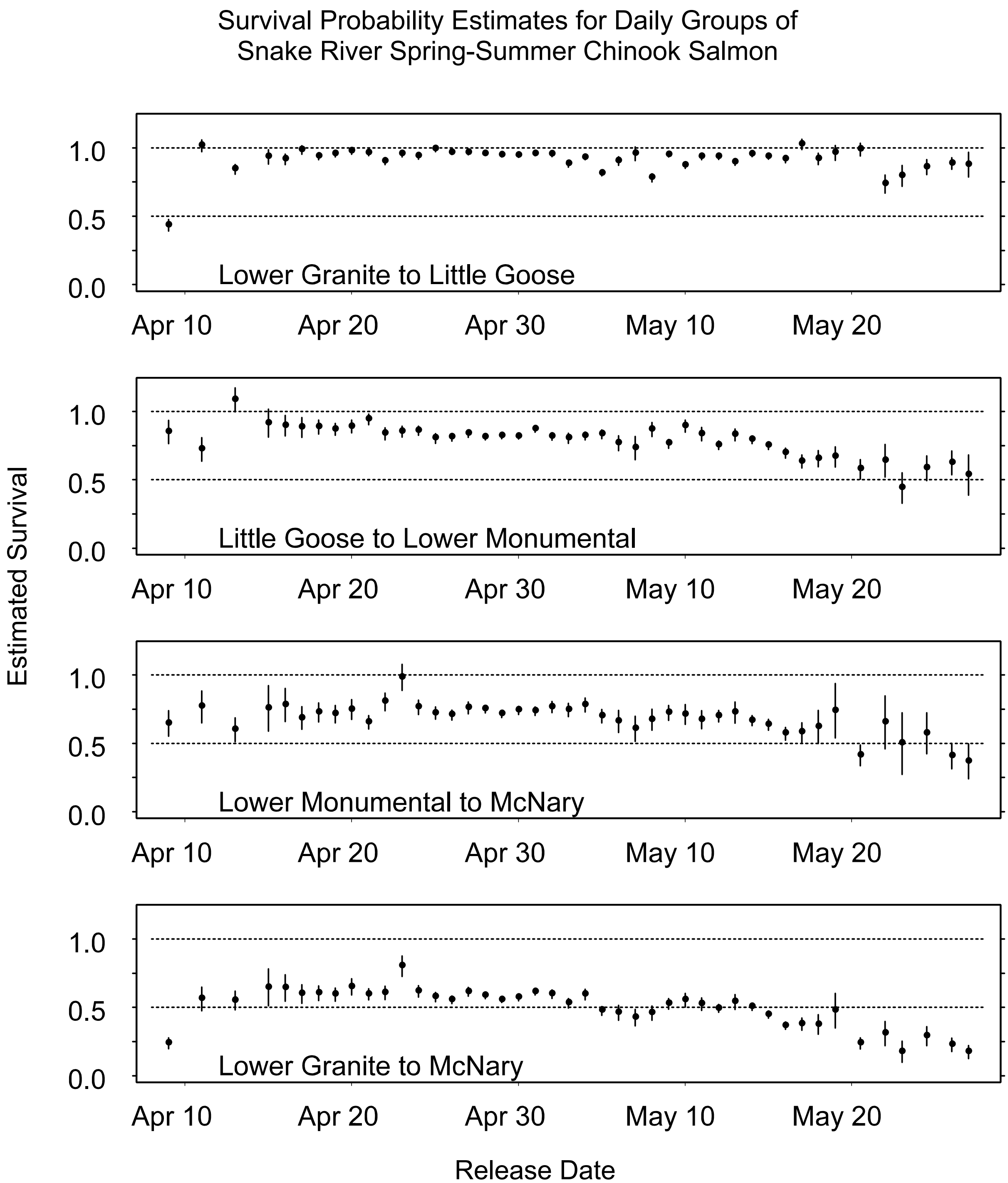


Figure 5. Estimated survival for daily release groups versus release date at Lower Granite Dam for Snake River spring-summer chinook salmon. The vertical bars represent +/- one standard error.

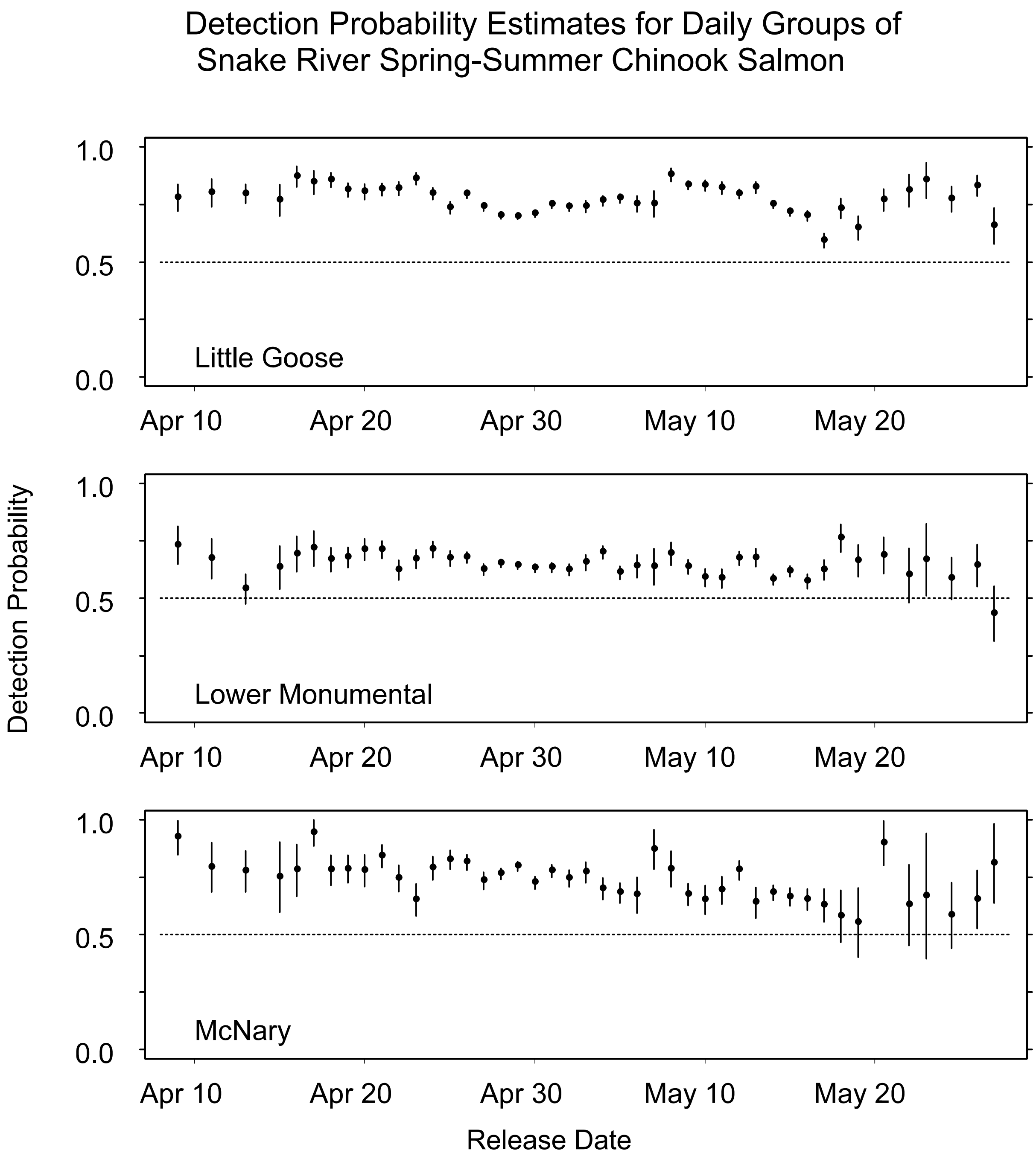


Figure 6. Estimated detection probability versus release date at Lower Granite Dam for Snake River spring-summer chinook salmon. The vertical bars represent +/- one standard error.

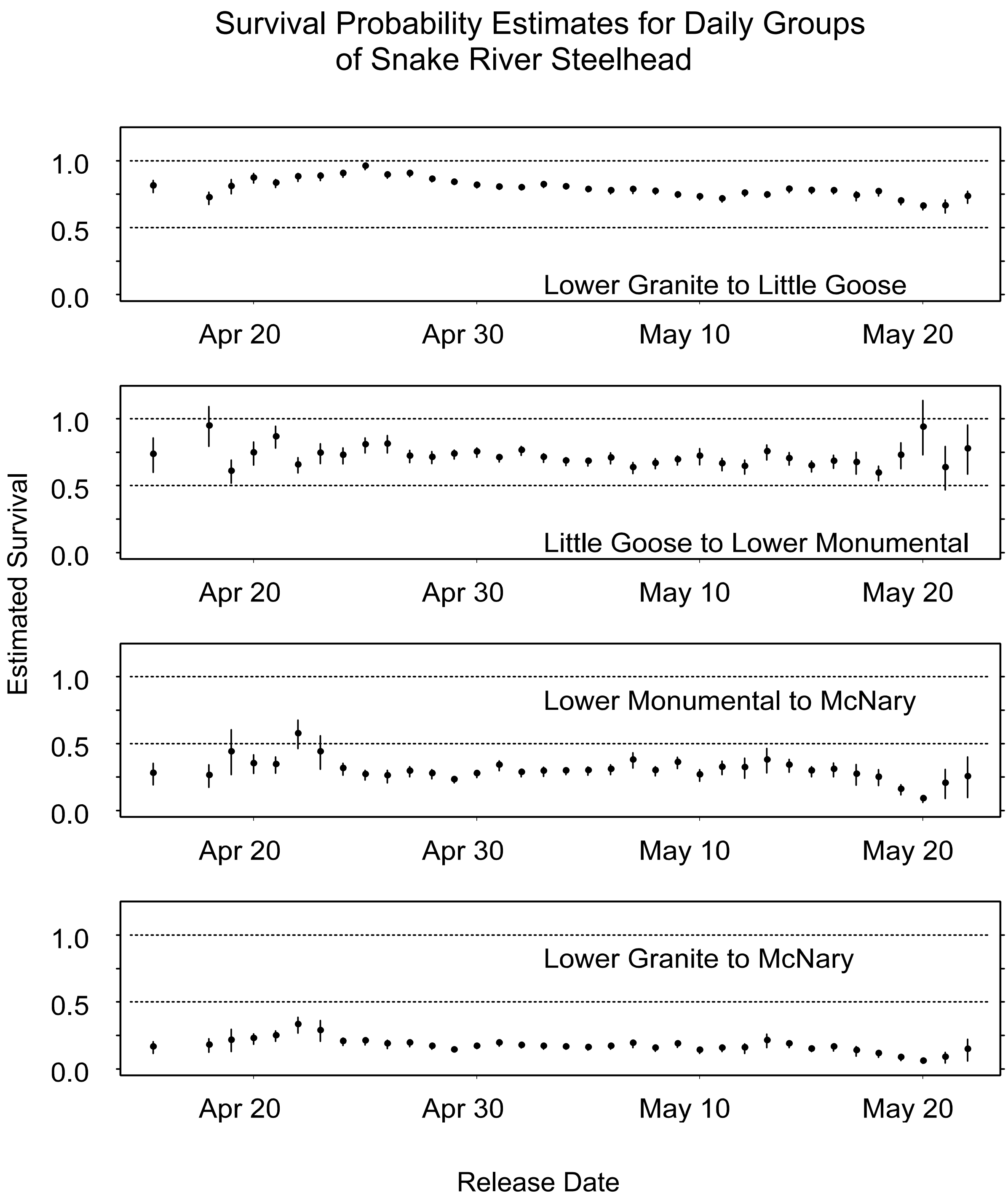


Figure 7. Estiamted survival for daily release groups versus release date at Lower Granite Dam for Snake River steelhead. The vertical bars represent +/- one standard error.

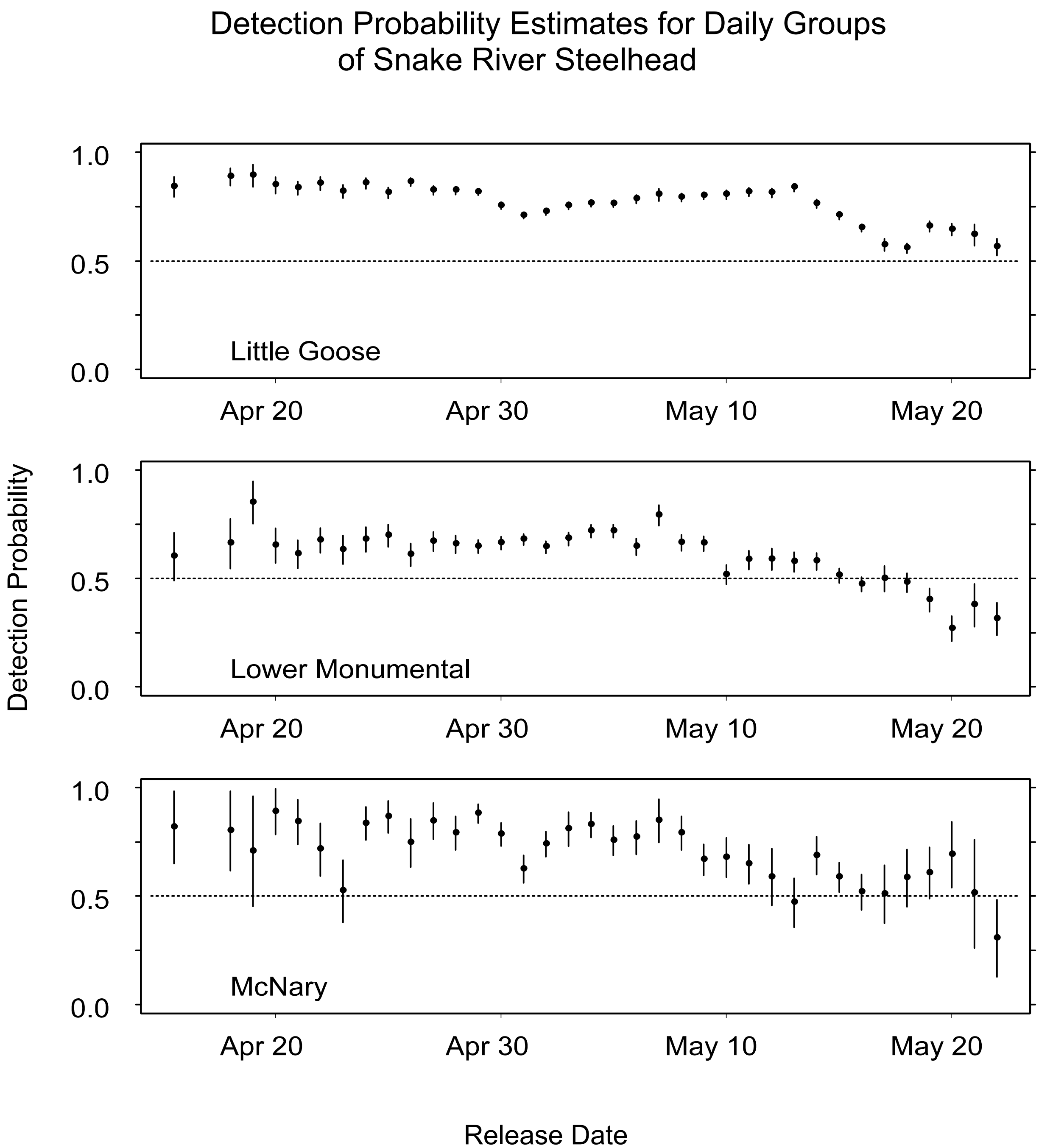


Figure 8. Estimated detection probability versus release date at Lower Granite Dam for Snake River steelhead. The vertical bars represent +/- one standard error.

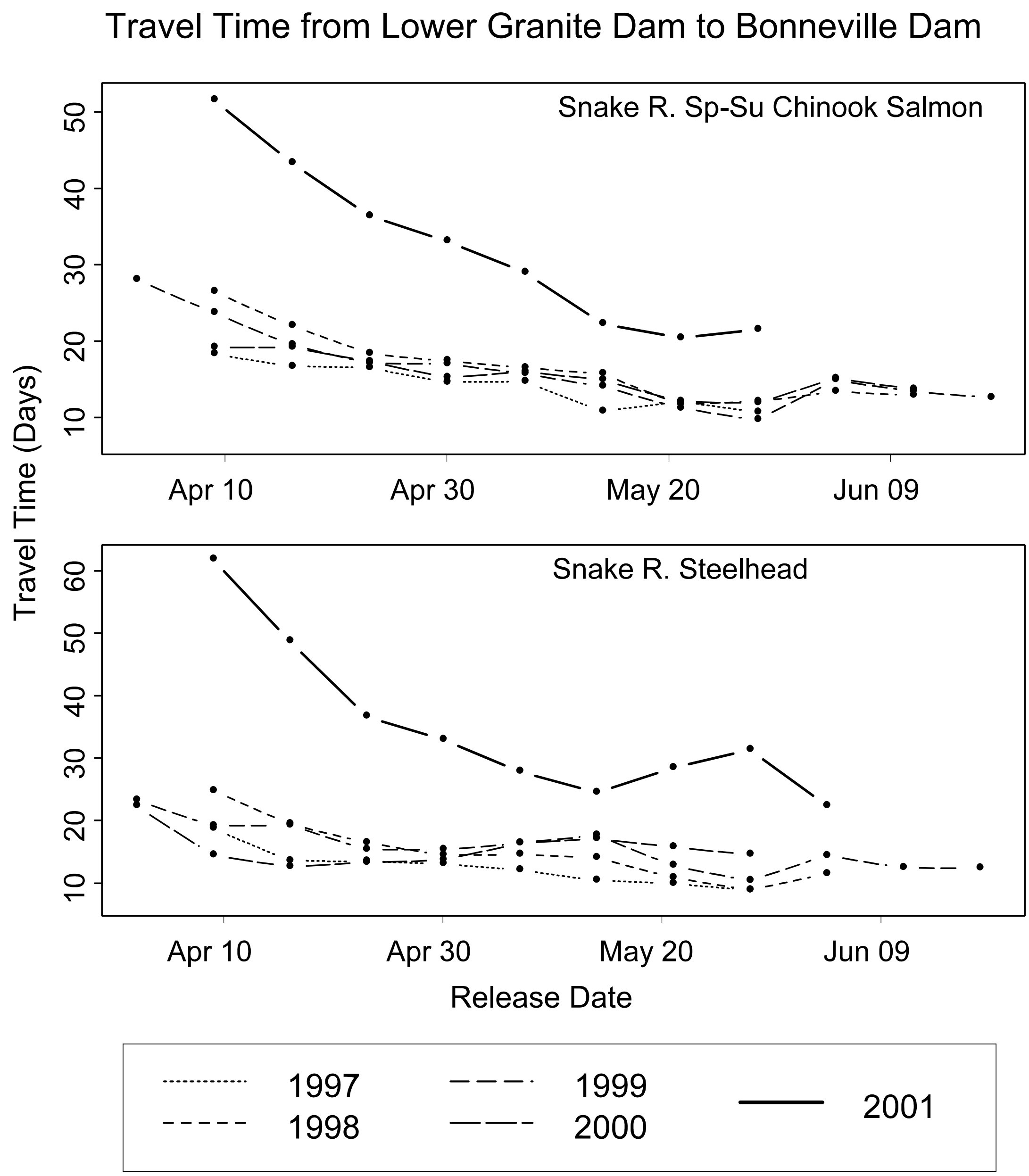


Figure 9. Median travel time (days) from Lower Granite Dam to Bonneville Dam for weekly release groups from Lower Granite Dam, 1997-2001.

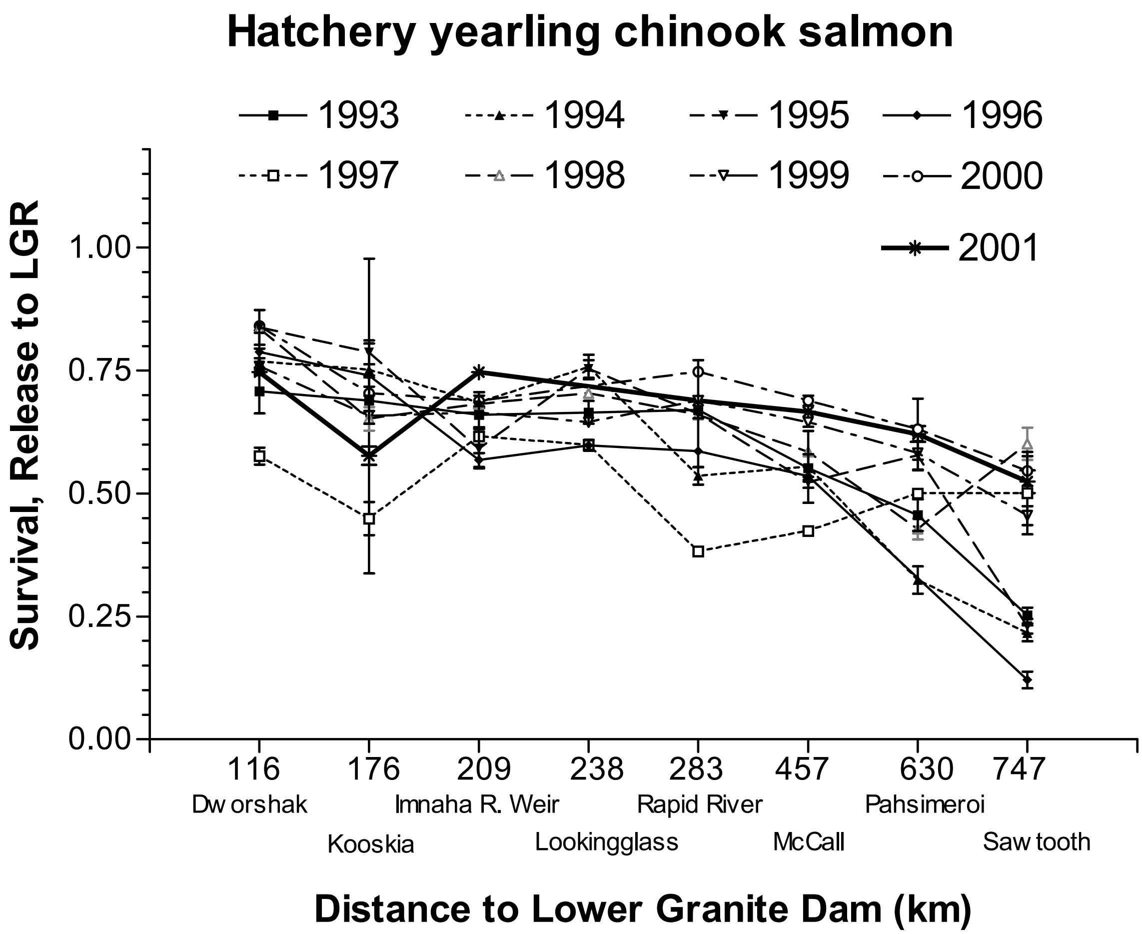


Figure 10. Estimated survival to Lower Granite Dam (LGR) tailrace for PIT-tagged yearling chinook salmon released from Snake River Basin hatcheries. Distance from release to Lower Granite Dam (km) and standard errors also shown.

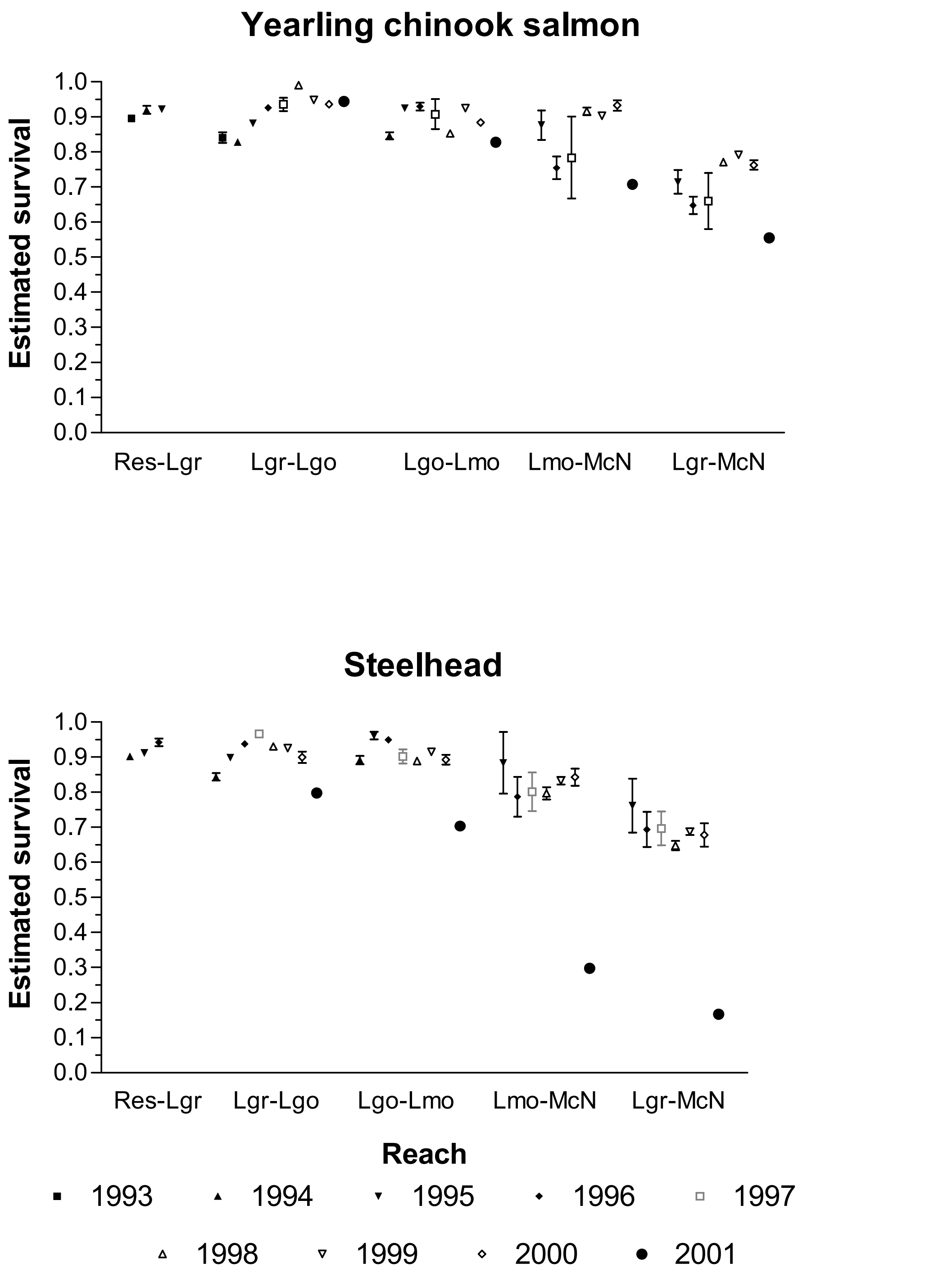


Figure 11. Annual average survival estimates for PIT-tagged yearling chinook salmon and steelhead from Lower Granite Reservoir (RES) to Lower Granite Dam (LGR), to Little Goose Dam (LGO), to Lower Monumental Dam (LMO), and to McNary Dam (MCN).

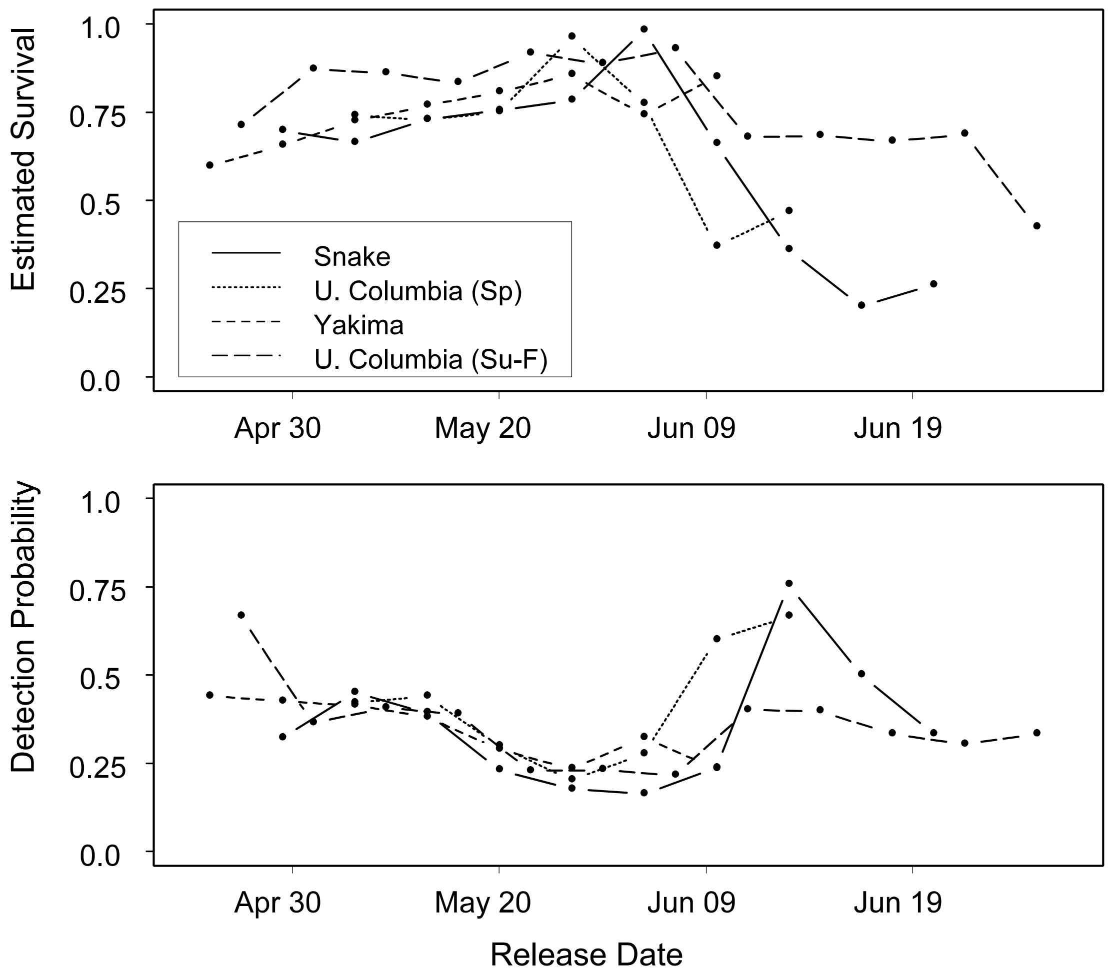


Figure 12. Estimated survival and detection probabilities for yearling chinook salmon migrating through John Day pool. Survival was estimated from McNary tailrace to John Day tailrace. Detection probabilities were estimated at John Day Dam. The fish were pooled into weekly groups based on detection date at McNary Dam. The points in the plots above represent the mid points of these weekly groups. The upper Columbia River fish were separated into spring and summer-fall stocks. See text for more details on the individual stocks. Abbreviations: Sp-Spring; Su-F-Summer-Fall.

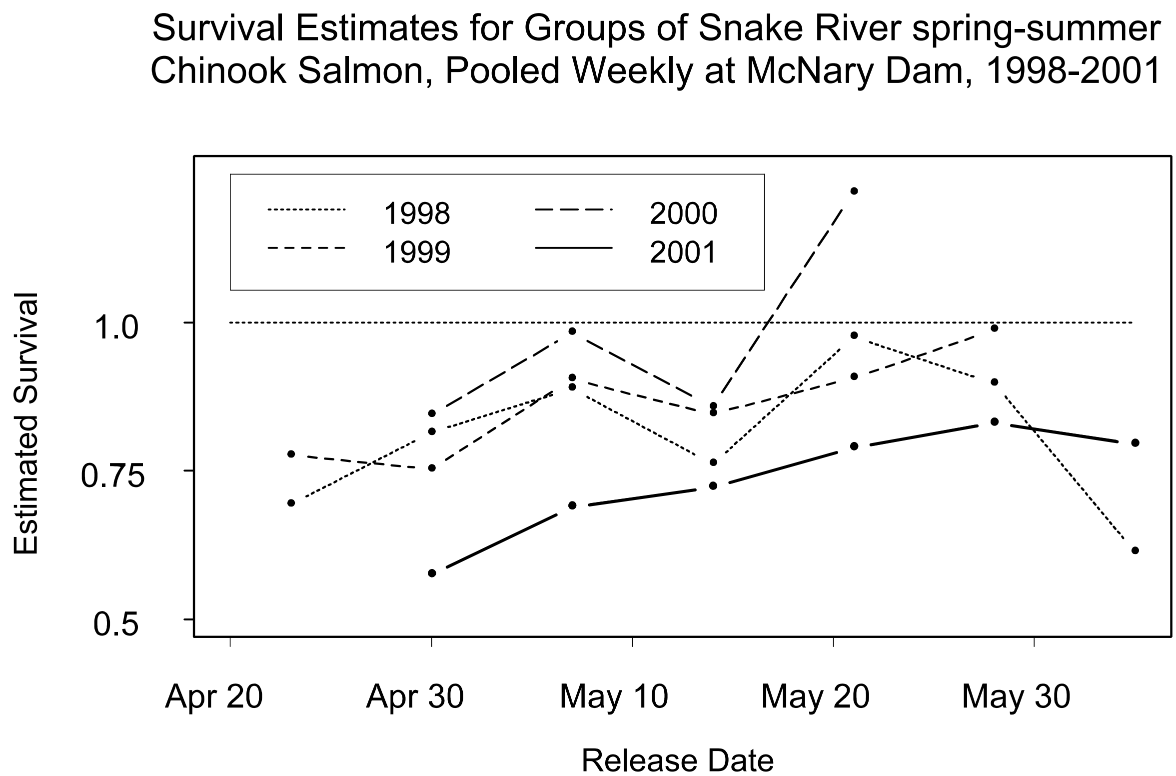


Figure 13. Estimated survival from McNary Dam tailrace to John Day Dam tailrace for Snake River spring-summer chinook salmon pooled into weekly groups at McNary Dam, 1998-2001.

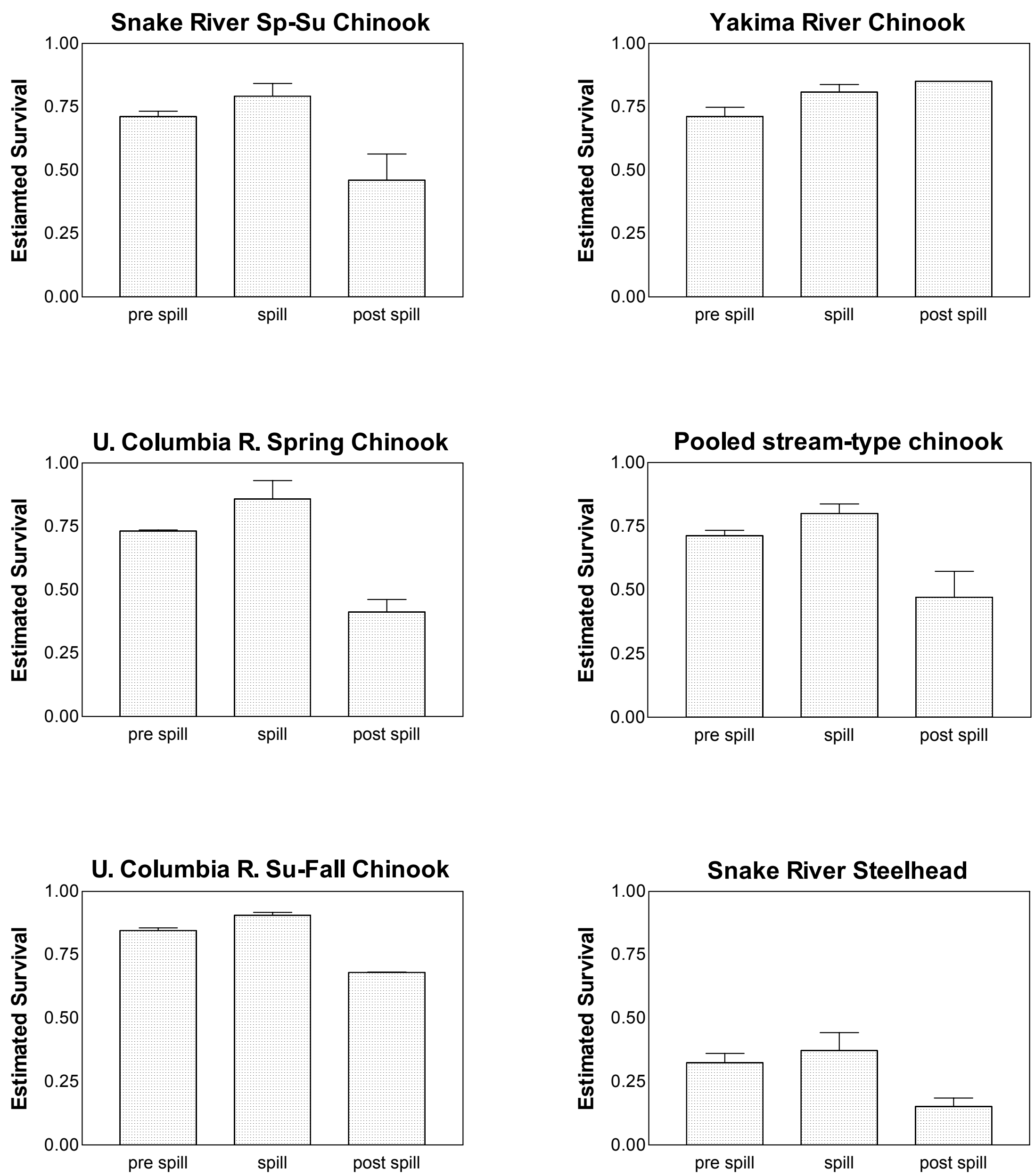


Figure 14. Average estimated survival from McNary Dam tailrace to John Day Dam tailrace by stock for the pre-spill, spill, and post-spill periods. The line above each bar represents one standard error.

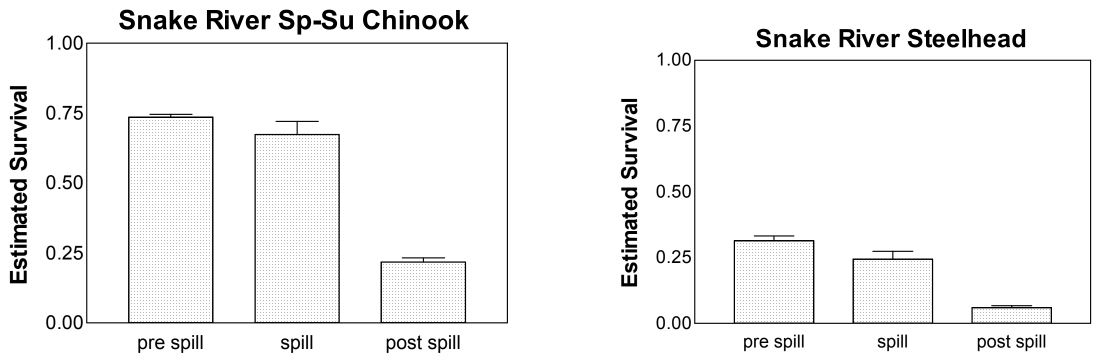


Figure 15. Average estimated survival from Lower Monumental Dam to McNary Dam tailrace by stock for the pre-spill, spill, and post-spill periods. The line above each bar represents one standard error.

Appendix 1: Tests of Model Assumptions

Background

Using the Cormack-Jolly-Seber (CJS), or Single-Release (SR) Model, the passage of a single PIT-tagged salmonid through the hydropower system is modeled as a sequence of events. Examples of such events are survival from the tailrace of Lower Granite Dam to the tailrace of Little Goose Dam, and detection at Little Goose Dam. Each event has an associated probability of occurrence (technically, these probabilities are "conditional", as they are defined only if a certain condition is met, for example "probability of detection at Little Goose Dam *given* that the fish survived to Little Goose Dam").

The detection history, then, is the record of the outcomes of the series of events. (The detection history is an imperfect record of outcomes; if the history ends with one or more "zeroes," we cannot distinguish mortality from survival without detection). The SR Model represents detection history data for a group of tagged fish as a multinomial distribution; each multinomial cell probability (detection history probability) is a function of the underlying survival and detection event probabilities. Three key assumptions lead to the multinomial cell probabilities used in the SR Model:

A1) Fish in a single group of tagged fish have common event probabilities (each conditional detection or survival probability is common to all fish in the group).

A2) Event probabilities for each individual fish are independent from those for all other fish.

A3) Each event probability for an individual fish is conditionally independent from all other probabilities.

For a migrating PIT-tagged fish, assumption A3 implies that detection at any particular dam does not affect (or give information regarding) probabilities of subsequent events. For the group as a whole, this means that detected and nondetected fish at a given dam have the same probability of survival in downstream reaches, and have the same conditional probability of detection at downstream dams.

Methods

We used the methods presented by Burnham et al. (1997; pp 71-77) to assess the goodness-of-fit of the SR model to observed detection history data. In these tests, we compiled a series of contingency tables from detection history data for each group of tagged fish, and used χ^2 tests to identify systematic deviations from what was expected if the assumptions were met. We applied the tests to weekly groups of yearling chinook salmon and steelhead (hatchery and wild combined) leaving Lower Granite and McNary dams (Snake River-origin fish only) between 1999 and 2001 (i.e., the fish used for survival estimates reported in Tables 1, 2, 10, and 11 for 2001, and corresponding survival estimates in previous years).

If goodness-of-fit tests for a series of release groups resulted in more significant tests than expected by chance, we compared observed and expected tables to determine the nature of the violation. While consistent patterns of violations in the assumption testing do not unequivocally pinpoint the cause of the violation, they can be suggestive, and some hypothesized causes may be ruled out.

Potential causes of assumption violations include inherent differences between individuals in survival or detectability (e.g., propensity to be guided by bypass screens), differential mortality between the passage route that is monitored for PIT tags (juvenile collection system) and those that are not (spillways and turbines), or behavioral responses to bypass and detection. Using detection information, inherent differences and behavioral responses are virtually indistinguishable. Conceptually, we make the distinction that inherent traits are those that characterized the fish before any hydrosystem experience, while behavioral responses occur as a result of particular hydrosystem experiences. For example, developing a preference for a particular passage route is a behavioral response, while size-related differences in passage-route selection are inherent. Of course, response to passage experience may also depend on inherent characteristics.

To describe each test we conducted, we follow the nomenclature of Burnham et al. (1987). For release groups from Lower Granite Dam, we analyzed 4-digit detection histories indicating status at Little Goose, Lower Monumental, and McNary Dams, and the final digit for detection anywhere below McNary Dam.

The first test for Lower Granite Dam groups was "Test 2.C2," which is based on the contingency table:

Test 2.C2	First Site detected below LGO		
df = 2	LMN	MCN	JDA or below
Not detected at LGO	n_{11}	n_{12}	n_{13}
Detected at LGO	n_{21}	n_{22}	n_{23}

In this table, all fish that were detected somewhere below Little Goose Dam are cross-classified according to their history at Little Goose Dam and according to their first detection site below Little Goose Dam (e.g., n_{11} is the number of fish not detected at Little Goose Dam that were first detected downstream at Lower Monumental Dam). If all assumptions were met, the counts for fish detected at LGO should be in constant proportion to those for fish not detected (i.e., n_{11}/n_{21}, n_{12}/n_{22}, and n_{13}/n_{23} should be equal). Because this table counts only fish detected below LGO (i.e., all fish survived LGO passage), differential *direct* mortality for fish detected and not detected at LGO will not cause violations of Test 2.C2 by itself. However, differential *indirect* mortality related to LGO passage could cause violations if differences are not expressed until fish are below LMO. Behavioral response to guidance at LGO could cause violations of Test 2.C2. If fish detected at LGO become more likely to be detected downstream, then they will tend to have more first downstream detections at LMO. If detected fish at LGO become less likely to be detected downstream, then they will have fewer first detections at LMO. Inherent differences among fish could also cause violations of Test 2.C2, and would be difficult to distinguish from behavioral responses.

The second test for Lower Granite Dam groups was Test 2.C3, based on the contingency table:

Test 2.C3	First site detected below LMN	
df = 1	MCN	JDA or below
Not detected at LMN	n_{11}	n_{12}
Detected at LMN	n_{21}	n_{22}

This table and corresponding implications are similar to Test 2.C2. All fish that were detected somewhere below LMN are cross-classified according to their history at LMN and according to their first detection site below LMN. If the respective counts for fish first detected at MCN are not in the same proportion as those first detected at JDA or below, it could indicate behavioral response to detection at LMN, inherent differences in detectability (i.e., guidability) among tagged fish in the group, or long-term differential mortality caused by different passage routes at LMN.

The next series of tests for Lower Granite Dam groups is called Test 3. The first in the series is called Test 3.SR3, based on the contingency table:

Test 3.SR3	Detected again at MCN or below?	
df = 1	YES	NO
Detected at LMN Not detected at LGO	n_{11}	n_{12}
Detected at LMN Detected at LGO	n_{21}	n_{22}

In this table, all fish detected at LMN are cross-classified according to their status at LGO and whether or not they were detected again downstream from LMN. As with the Test 2 series, differential mortality in different passage routes at LGO will not be detected by this test if all the mortality is expressed before the fish arrive at LMN. Differences in mortality expressed below MCN could cause violations, however, as could behavioral responses (possibly somewhat harder to detect because of the conditioning on detection at LMN) or inherent differences in detectability or survival between fish detected at LGO and those not detected there.

The second test in the Test 3 series is Test 3.Sm3, based on the contingency table:

Test 3.Sm3	Site first detected below LMN	
df = 1	MCN	JDA
Detected at LMN Not detected at LGO	n_{11}	n_{12}
Detected at LMN Detected at LGO	n_{21}	n_{22}

This test is sensitive to the same sorts of differences as Test 3.SR3, but tends to have somewhat less power. Because the table classifies only fish detected somewhere below LMN, it is not sensitive to differences in survival between LMN and MCN.

The final test for Lower Granite Dam groups is Test 3.SR4, based on the contingency table:

Test 3.SR4	Detected at JDA or below?	
df = 1	Yes	No
Detected at MCN, not detected previously	n_{11}	n_{12}
Detected at MCN, also detected previously	n_{21}	n_{22}

This table classifies all fish detected at MCN according to whether they had been detected at least once at LGO and LMN and whether they were detected again below MCN. A significant test indicates that some below-MCN parameter(s) differ between fish detected above MCN and those not detected. The cause of such an assumption violation could be differences in indirect survival associated with detection at LGO and/or LMN (mortality expressed between MCN and the estuary PIT-trawl), inherent differences in survival or detection probabilities, or behavioral responses.

We did not include any contingency table tests when any of the expected cells of the table were less than 1.0, as the test statistic does not sufficiently approximate the asymptotic χ^2 distribution in these cases. (For Test 2.C2, when the expected values in the "LMN" and "MCN" columns were all greater than 1.0, but one or two of the expected values in the "JDA or below" column were less than 1.0, we collapsed the "MCN" and "JDA or below" and calculated a one-degree-of-freedom test of the resulting 2-by-2 table). We combined the two test statistics in the Test 2 series and the three in the Test 3 series and then all tests together in a single overall χ^2 test statistic.

For release groups from McNary Dam, we analyzed 3-digit detection histories indicating status at John Day Dam, Bonneville Dam, and the estuary PIT-trawl.

Only two tests are possible for 3-digit detection histories. The first of these was Test 2.C2, based on the contingency table:

Test 2.C2	First site detected below JDA	
df = 1	BON	Trawl
Not detected at JDA	n_{11}	n_{12}
Detected at JDA	n_{21}	n_{22}

and the second is Test 2.SR3, based on the contingency table:

Test 3.SR3	Detected at Trawl	
df = 1	Yes	No
Detected at BON, not detected at JDA	n_{11}	n_{12}
Detected at BON, detected at JDA	n_{21}	n_{22}

These tests are analogous to Tests 2.C3 and 3.SR4, respectively, for the Lower Granite Dam release groups. Potential causes of violations of the tests for McNary Dam groups are the same as those for Lower Granite Dam groups.

Results

For weekly Lower Granite Dam release groups from 1999 through 2001 there were more significant ($\alpha = 0.05$) tests of goodness of fit than expected by chance alone, especially for steelhead (Table A1.1). There were 30 weekly groups of yearling chinook salmon over the 3 years. For these, the overall sum of the χ^2 test statistics was significant 9 times. For 29 steelhead groups, the overall test was significant 18 times. Counting individual tests (e.g., 2.C2, 3.SR3), 21 tests of 150 (14%) were significant for yearling chinook salmon and 50 of 135 (37%) were significant for steelhead (Tables A1.1 through A1.7). For both species, the most frequently significant test was 2.C2.

We diagnosed the patterns in the contingency tables that led to significant results and discovered an overwhelmingly predominant result: in 16 of the 21 significant cases for yearling chinook salmon and in 45 of the 50 cases for steelhead, there was evidence that fish previously detected were more likely to be detected again at downstream dams. A typical result is illustrated by the following contingency tables for Tests 2.C2 and Test 3.SR3 for steelhead leaving Lower Granite Dam between 4 and 11 May, 2001:

Test 2.C2	First Site detected below LGO		
df = 2	LMN	MCN	JDA or below
Not detected at LGO	709	105	12
Detected at LGO	2627	252	24

Test 3.SR3	Detected again at MCN or below?	
df = 1	YES	NO
Detected at LMN Not detected at LGO	134	541
Detected at LMN Detected at LGO	654	1884

These tables indicate, respectively, that fish detected at LGO were more likely than fish not detected there to have their next detection downstream at LMN, and that fish detected at LGO and LMN were more likely to be detected at MCN or below than those detected only at LMN.

Significant contingency table test results were far less common for weekly groups from McNary Dam (Tables A1.8 through A1.14).

Discussion

We believe that inherent differences in detectability (guidability) of fish within a release group are the most likely cause of the patterns we observed in the contingency table tests.

Detected and nondetected fish at a particular dam took different passage routes. During the spring migration, direct and indirect mortality through the various passage routes at Snake River dams is thought to be lowest through spillways and highest through turbines, and the juvenile bypass facility is intermediate. While the tests cannot detect differences in direct mortality, differential indirect mortality expressed downstream could cause significant test results. In 2001 there was no spill at Snake River dams, so we know that detected fish passed via the juvenile collection facility, while nondetected fish passed through turbines. In 1999 and 2000 considerably more nondetected fish passed via spillways at Snake River dams. We do not believe that differential indirect mortality was the cause of the significant lack of fit, because we did not see a switch in the patterns observed in the contingency tables as nondetected fish "switched" from spillway passage in 1999 and especially 2000 to turbine passage in 2001.

The contingency table tests cannot distinguish between differences in inherent propensity to be detected (resulting from differences in probabilities of choosing spillway versus powerhouse passage, and differences in guidability) and behavioral responses to a previous experience of being guided. We know of no evidence, however, of a behavioral response that would make a fish more likely to pass via the bypass system of a downstream dam after having used the route at a previous dam.

On the other hand, Appendix 2 provides evidence of inherent differences related to length of fish at tagging. Fish size probably does not explain all inherent differences, but it appears to explain some. The relationship between length at tagging and detection probability at Little Goose Dam, the first dam encountered after release by fish in these data sets (all fish in the data set were detected at Lower Granite Dam; Little Goose Dam is the first encountered after leaving LGR) suggests the heterogeneity is inherent, and not a behavioral response.

As an example of the degree of heterogeneity present, for steelhead leaving Lower Granite Dam between 4 and 11 May, 2001, the CJS estimate of detection probability at Lower Monumental Dam is 0.675. Applying CJS separately, the estimate is 0.710 for fish that were previously detected at Little Goose Dam and 0.546 for fish that were not detected there. At McNary Dam, the pooled detection probability estimate was 0.755. Classifying fish by their previous detection history, the estimate was 0.864 for fish detected at both LGO and LMO, 0.729 for fish detected only at LMO, 0.523 for those detected only at LGO, and 0.500 for those not detected at either dam.

Analyses in Appendix 2 shed light on the effects (potential bias) of length-related heterogeneity on survival estimates (and on the relation between length and survival). The effects are small, consistent with the conclusion of Burnham et al. (1987, p. 287): "In the presence of heterogeneity, the parameters are weakly dependent on previous [detection] histories. In addition, the assumption of independence is violated, but the effect on the statistical properties is often quite small. We tentatively conclude that a reasonable amount of heterogeneity in the survival and [detection] process will not seriously affect the performance of estimators of ... survival."

References

Burnham, K. P., D. R. Anderson, G. C. White, C. Brownie, and K. H. Pollock. 1987. Design and analysis methods for fish survival experiments based on release-recapture. American Fisheries Society Monograph 5.

Table A1.1. Number of tests of goodness of fit to the Single Release Model conducted for weekly release groups of yearling chinook salmon and steelhead (hatchery and wild combined) from Lower Granite Dam, and number of significant (α = 0.05) test results, 1999-2001.

		Test 2.C2		Test 2.C3		Test 3.SR3		Test 3.Sm3		Test 3.SR4		Test 2 sum		Test 3 sum		Test 2 + 3	
Year	Spp.	No.	sig.	No.	sig.	No.	sig.	No.	sig.	No.	sig.	No.	sig.	No.	sig.	No.	sig.
2001	Ch.	9	3	9	1	9	2	9	2	9	0	9	4	9	1	9	4
2001	St.	9	6	7	4	9	3	5	2	6	1	9	7	9	5	9	7
2000	Ch.	10	2	10	0	10	2	10	0	10	1	10	2	10	1	10	2
2000	St.	9	3	9	2	9	3	9	1	8	2	9	3	9	4	9	3
1999	Ch.	11	2	11	2	11	1	11	2	11	1	11	3	11	0	11	3
1999	St.	11	4	11	6	11	5	11	3	11	5	11	8	11	8	11	8
Tot.	Ch.	30	7	30	3	30	5	30	4	30	4	30	9	30	2	30	9
Tot.	St.	29	13	27	12	29	11	25	6	25	8	29	18	29	17	29	18

Table A1.2. Results of tests of goodness of fit to the Single Release Model for release groups of yearling chinook salmon (hatchery and wild) from Lower Granite to McNary Dam in 2001.

	Overall		Test 2		Test 2.C2		Test 2.C3	
Release	χ^2	P value	χ^2	P value	χ^2	P value	χ^2	P value
06 Apr - 12 Apr	7.602	0.180	4.554	0.103	3.532	0.060	1.023	0.312
13 Apr - 19 Apr	7.630	0.266	1.860	0.602	1.839	0.399	0.021	0.886
20 Apr - 26 Apr	13.831	0.032	11.134	0.011	6.558	0.038	4.575	0.032
27 Apr - 03 May	18.393	0.005	8.412	0.038	8.200	0.017	0.211	0.646
04 May - 10 May	10.726	0.097	4.606	0.203	3.920	0.141	0.686	0.408
11 May - 17 May	29.756	0.000	24.637	0.000	23.223	0.000	1.414	0.234
18 May - 24 May	10.664	0.099	8.822	0.032	5.217	0.074	3.604	0.058
25 May - 31 May	4.676	0.586	4.261	0.235	3.422	0.181	0.839	0.360
01 Jun - 07 Jun	NA	NA	NA	NA	NA	NA	NA	NA

Table A1.2. Continued.

Release	Test 3		Test 3.SR3		Test 3.Sm3		Test 3.SR4	
	χ^2	P value	χ^2	P value	χ^2	P value	χ^2	P value
06 Apr - 12 Apr	3.047	0.384	0.372	0.542	1.729	0.189	0.946	0.331
13 Apr - 19 Apr	5.770	0.123	0.228	0.633	3.850	0.050	1.692	0.193
20 Apr - 26 Apr	2.697	0.441	0.124	0.725	2.359	0.125	0.215	0.643
27 Apr - 03 May	9.982	0.019	9.981	0.002	0.000	0.984	0.000	0.999
04 May - 10 May	6.119	0.106	0.403	0.526	4.023	0.045	1.694	0.193
11 May - 17 May	5.119	0.163	4.044	0.044	0.852	0.356	0.223	0.637
18 May - 24 May	1.842	0.606	1.455	0.228	0.050	0.824	0.338	0.561
25 May - 31 May	0.414	0.937	0.029	0.864	0.070	0.792	0.316	0.574
01 Jun - 07 Jun	NA	NA	NA	NA	NA	NA	NA	NA

Table A1.3. Results of tests of goodness of fit to the Single Release Model for release groups of juvenile steelhead (hatchery and wild) from Lower Granite to McNary Dam in 2001.

	Overall		Test 2		Test 2.C2		Test 2.C3	
Release	χ^2	P value	χ^2	P value	χ^2	P value	χ^2	P value
06 Apr - 12 Apr	2.711	0.258	1.511	0.219	1.511	0.219	NA	NA
13 Apr - 19 Apr	5.414	0.144	3.730	0.155	0.835	0.361	2.896	0.089
20 Apr - 26 Apr	16.826	0.010	9.348	0.025	4.122	0.127	5.225	0.022
27 Apr - 03 May	21.704	0.001	13.525	0.004	9.559	0.008	3.965	0.046
04 May - 10 May	51.629	0.000	39.169	0.000	15.085	0.001	24.084	0.000
11 May - 17 May	74.317	0.000	47.048	0.000	26.212	0.000	20.836	0.000
18 May - 24 May	23.072	0.001	17.186	0.001	15.524	0.000	1.662	0.197
25 May - 31 May	15.169	0.010	11.016	0.012	8.522	0.014	2.494	0.114
01 Jun - 07 Jun	13.778	0.003	9.349	0.009	9.349	0.009	NA	NA

Table A1.3. Continued.

	Test 3		Test 3.SR3		Test 3.Sm3		Test 3.SR4	
Release	χ^2	P value	χ^2	P value	χ^2	P value	χ^2	P value
06 Apr - 12 Apr	1.200	0.273	1.200	0.273	NA	NA	NA	NA
13 Apr - 19 Apr	1.683	0.194	1.683	0.194	NA	NA	NA	NA
20 Apr - 26 Apr	7.478	0.058	0.461	0.497	5.676	0.017	1.340	0.247
27 Apr - 03 May	8.179	0.042	0.449	0.503	1.480	0.224	6.250	0.012
04 May - 10 May	12.460	0.006	10.020	0.002	2.045	0.153	0.395	0.530
11 May - 17 May	27.269	0.000	21.067	0.000	4.042	0.044	2.160	0.142
18 May - 24 May	5.886	0.117	2.007	0.157	0.431	0.511	3.448	0.063
25 May - 31 May	4.152	0.125	0.438	0.508	NA	NA	3.714	0.054
01 Jun - 07 Jun	4.429	0.035	4.429	0.035	NA	NA	NA	NA

Table A1.4. Results of tests of goodness of fit to the Single Release Model for release groups of yearling chinook salmon (hatchery and wild) from Lower Granite to McNary Dam in 2000.

	Overall		Test 2		Test 2.C2		Test 2.C3	
Release	χ^2	P value	χ^2	P value	χ^2	P value	χ^2	P value
06 Apr - 12 Apr	2.296	0.891	0.137	0.987	0.085	0.958	0.052	0.819
13 Apr - 19 Apr	11.663	0.070	6.438	0.092	5.442	0.066	0.995	0.318
20 Apr - 26 Apr	4.560	0.601	1.809	0.613	1.712	0.425	0.097	0.755
27 Apr - 03 May	16.160	0.013	12.344	0.006	11.890	0.003	0.453	0.501
04 May - 10 May	22.308	0.001	10.037	0.018	10.035	0.007	0.002	0.964
11 May - 17 May	10.967	0.089	5.143	0.162	4.475	0.107	0.668	0.414
18 May - 24 May	6.979	0.323	5.291	0.152	2.959	0.228	2.332	0.127
25 May - 31 May	2.459	0.873	1.619	0.655	0.317	0.854	1.302	0.254
01 Jun - 07 Jun	2.416	0.878	2.051	0.562	0.237	0.888	1.814	0.178
08 Jun - 14 Jun	7.688	0.262	2.976	0.395	2.959	0.228	0.017	0.895

Table A1.4. Continued

Release	Test 3		Test 3.SR3		Test 3.Sm3		Test 3.SR4	
	χ^2	P value	χ^2	P value	χ^2	P value	χ^2	P value
06 Apr - 12 Apr	2.158	0.540	0.034	0.855	1.558	0.212	0.566	0.452
13 Apr - 19 Apr	5.226	0.156	4.812	0.028	0.348	0.555	0.065	0.798
20 Apr - 26 Apr	2.751	0.432	0.556	0.456	0.000	0.983	2.195	0.138
27 Apr - 03 May	3.817	0.282	0.310	0.577	0.090	0.764	3.416	0.065
04 May - 10 May	12.271	0.007	1.002	0.317	0.035	0.851	11.234	0.001
11 May - 17 May	5.824	0.120	5.380	0.020	0.093	0.760	0.351	0.554
18 May - 24 May	1.688	0.640	0.328	0.567	0.087	0.768	1.273	0.259
25 May - 31 May	0.840	0.840	0.289	0.591	0.542	0.462	0.009	0.924
01 Jun - 07 Jun	0.365	0.947	0.255	0.614	0.109	0.742	0.001	0.970

Table A1.5. Results of tests of goodness of fit to the Single Release Model for release groups of juvenile steelhead (hatchery and wild) from Lower Granite to McNary Dam in 2000.

	Overall		Test 2		Test 2.C2		Test 2.C3	
Release	χ^2	P value	χ^2	P value	χ^2	P value	χ^2	P value
30 Mar - 05 Apr	7.978	0.240	3.403	0.333	3.289	0.193	0.115	0.735
06 Apr - 12 Apr	8.297	0.217	2.948	0.400	2.681	0.262	0.267	0.606
13 Apr - 19 Apr	43.788	0.000	29.641	0.000	7.171	0.028	22.470	0.000
20 Apr - 26 Apr	30.818	0.000	22.004	0.000	13.494	0.001	8.510	0.004
27 Apr - 03 May	29.095	0.000	6.497	0.090	2.967	0.227	3.530	0.060
04 May - 10 May	35.103	0.000	16.051	0.001	12.788	0.002	3.263	0.071
11 May - 17 May	9.360	0.154	5.591	0.133	5.028	0.081	0.562	0.453
18 May - 24 May	2.925	0.818	1.310	0.727	0.905	0.636	0.405	0.524
25 May - 31 May	5.777	0.329	5.702	0.127	4.982	0.083	0.720	0.396

Table A1.5. Continued

	Test 3		Test 3.SR3		Test 3.Sm3		Test 3.SR4	
Release	χ^2	P value	χ^2	P value	χ^2	P value	χ^2	P value
30 Mar - 05 Apr	4.574	0.206	1.042	0.307	0.000	1.000	3.533	0.060
06 Apr - 12 Apr	5.349	0.148	1.817	0.178	0.089	0.766	3.443	0.064
13 Apr - 19 Apr	14.147	0.003	8.800	0.003	1.744	0.187	3.603	0.058
20 Apr - 26 Apr	8.815	0.032	1.105	0.293	1.220	0.269	6.490	0.011
27 Apr - 03 May	22.599	0.000	14.311	0.000	7.529	0.006	0.758	0.384
04 May - 10 May	19.052	0.000	6.818	0.009	0.223	0.637	12.011	0.001
11 May - 17 May	3.770	0.287	0.657	0.417	1.693	0.193	1.419	0.234
18 May - 24 May	1.615	0.656	0.869	0.351	0.038	0.846	0.708	0.400
25 May - 31 May	0.075	0.963	0.075	0.785	0.000	1.000	NA	NA

Table A1.6. Results of tests of goodness of fit to the Single Release Model for release groups of yearling chinook salmon (hatchery and wild) from Lower Granite to McNary Dam in 1999.

	Overall		Test 2		Test 2.C2		Test 2.C3	
Release	χ^2	P value	χ^2	P value	χ^2	P value	χ^2	P value
30 Mar - 05 Apr	6.175	0.404	4.986	0.173	4.958	0.084	0.028	0.866
06 Apr - 12 Apr	3.679	0.720	1.323	0.724	1.082	0.582	0.241	0.624
13 Apr - 19 Apr	4.881	0.559	1.250	0.741	1.233	0.540	0.017	0.896
20 Apr - 26 Apr	5.615	0.468	2.120	0.548	2.097	0.350	0.023	0.881
27 Apr - 03 May	6.077	0.415	0.483	0.923	0.479	0.787	0.004	0.949
04 May - 10 May	13.544	0.035	9.960	0.019	2.431	0.297	7.529	0.006
11 May - 17 May	10.666	0.099	6.343	0.096	3.753	0.153	2.590	0.108
18 May - 24 May	21.111	0.002	13.862	0.003	9.606	0.008	4.256	0.039
25 May - 31 May	32.505	0.000	28.724	0.000	25.744	0.000	2.980	0.084
01 Jun - 07 Jun	5.841	0.441	1.646	0.649	1.302	0.522	0.344	0.557
08 Jun - 14 Jun	12.025	0.061	4.764	0.190	1.845	0.397	2.919	0.088

Table A1.6. Continued.

	Test 3		Test 3.SR3		Test 3.Sm3		Test 3.SR4	
Release	χ^2	P value	χ^2	P value	χ^2	P value	χ^2	P value
30 Mar - 05 Apr	1.189	0.756	0.457	0.499	0.730	0.393	0.002	0.967
06 Apr - 12 Apr	2.356	0.502	0.681	0.409	0.276	0.599	1.399	0.237
13 Apr - 19 Apr	3.630	0.304	0.587	0.444	2.547	0.111	0.497	0.481
20 Apr - 26 Apr	3.495	0.321	0.036	0.849	0.272	0.602	3.187	0.074
27 Apr - 03 May	5.594	0.133	4.737	0.030	0.825	0.364	0.032	0.858
04 May - 10 May	3.584	0.310	0.000	0.986	1.367	0.242	2.216	0.137
11 May - 17 May	4.323	0.229	0.313	0.576	3.396	0.065	0.615	0.433
18 May - 24 May	7.250	0.064	0.004	0.947	0.931	0.335	6.314	0.012
25 May - 31 May	3.781	0.286	3.139	0.076	0.000	1.000	0.642	0.423
01 Jun - 07 Jun	4.195	0.241	0.021	0.884	3.985	0.046	0.188	0.664
08 Jun - 14 Jun	7.261	0.064	0.089	0.766	6.952	0.008	0.220	0.639

Table A1.7. Results of tests of goodness of fit to the Single Release Model for release groups of steelhead (hatchery and wild) from Lower Granite to McNary Dam in 1999.

	Overall		Test 2		Test 2.C2		Test 2.C3	
Release	χ^2	P value	χ^2	P value	χ^2	P value	χ^2	P value
30 Mar - 05 Apr	15.363	0.018	6.292	0.098	1.101	0.577	5.191	0.023
06 Apr - 12 Apr	25.011	0.000	22.552	0.000	8.254	0.016	14.298	0.000
13 Apr - 19 Apr	16.743	0.010	8.987	0.029	0.087	0.957	8.900	0.003
20 Apr - 26 Apr	22.740	0.001	10.671	0.014	0.464	0.793	10.208	0.001
27 Apr - 03 May	40.990	0.000	21.196	0.000	4.371	0.112	16.826	0.000
04 May - 10 May	44.435	0.000	11.423	0.010	3.424	0.180	7.999	0.005
11 May - 17 May	50.880	0.000	12.119	0.007	10.048	0.007	2.070	0.150
18 May - 24 May	37.516	0.000	10.009	0.018	8.986	0.011	1.023	0.312
25 May - 31 May	90.197	0.000	70.177	0.000	68.283	0.000	1.894	0.169
01 Jun - 07 Jun	12.400	0.054	2.752	0.431	1.822	0.402	0.930	0.335
08 Jun - 14 Jun	2.672	0.849	1.186	0.756	0.854	0.652	0.331	0.565

Table A1.7. Continued.

	Test 3		Test 3.SR3		Test 3.Sm3		Test 3.SR4	
Release	χ^2	P value	χ^2	P value	χ^2	P value	χ^2	P value
30 Mar - 05 Apr	9.071	0.028	0.642	0.423	4.042	0.044	4.387	0.036
06 Apr - 12 Apr	2.459	0.483	0.132	0.716	1.538	0.215	0.788	0.375
13 Apr - 19 Apr	7.756	0.051	1.056	0.304	3.203	0.074	3.497	0.061
20 Apr - 26 Apr	12.069	0.007	11.308	0.001	0.582	0.445	0.179	0.672
27 Apr - 03 May	19.793	0.000	3.581	0.058	0.692	0.405	15.520	0.000
04 May - 10 May	33.012	0.000	20.264	0.000	4.219	0.040	8.528	0.003
11 May - 17 May	38.761	0.000	31.063	0.000	0.897	0.344	6.801	0.009
18 May - 24 May	27.507	0.000	16.279	0.000	0.972	0.324	10.257	0.001
25 May - 31 May	20.020	0.000	1.669	0.196	17.309	0.000	1.042	0.307
01 Jun - 07 Jun	9.647	0.022	8.293	0.004	1.351	0.245	0.003	0.956
08 Jun - 14 Jun	1.486	0.685	1.219	0.270	0.129	0.720	0.138	0.710

Table A1.8. Number of tests of goodness of fit to the Single Release Model conducted for weekly release groups of yearling chinook salmon and steelhead (hatchery and wild combined) from McNary Dam, and number of significant ($\alpha = 0.05$) test results, 1999-2001.

		Test 2.C3		Test 3.SR4		Test 2 + 3	
Year	Spp.	#	sig.	#	sig.	#	sig.
2001	Ch.	6	0	6	1	6	0
2001	St.	4	0	4	0	4	0
2000	Ch.	4	0	4	0	4	0
2000	St.	4	0	4	0	4	0
1999	Ch.	6	1	6	2	6	2
1999	St.	6	1	6	1	6	1
Tot.	Ch.	16	1	16	3	16	2
Tot.	St.	14	1	14	1	14	1

Table A1.9. Results of tests of goodness of fit to the Single Release Model for release groups of yearling chinook salmon (hatchery and wild) from McNary to Bonneville Dam in 2001.

	Overall		Test 2.C2		Test 3.SR3	
Release	χ^2	P value	χ^2	P value	χ^2	P value
27 Apr - 03 May	2.197	0.333	1.631	0.202	0.566	0.452
04 May - 10 May	4.831	0.089	0.797	0.372	4.034	0.045
11 May - 17 May	1.686	0.430	0.785	0.376	0.901	0.343
18 May - 24 May	1.850	0.397	0.034	0.854	1.816	0.178
25 May - 31 May	5.077	0.079	2.381	0.123	2.696	0.101
01 Jun - 07 Jun	2.446	0.294	0.697	0.404	1.749	0.186

Table A1.10. Results of tests of goodness of fit to the Single Release Model for release groups of steelhead (hatchery and wild) from McNary to Bonneville Dam in 2001.

	Overall		Test 2.C2		Test 3.SR3	
Release	χ^2	P value	χ^2	P value	χ^2	P value
04 May - 10 May	2.266	0.322	1.096	0.295	1.170	0.279
11 May - 17 May	1.029	0.598	0.116	0.733	0.913	0.339
18 May - 24 May	0.281	0.869	0.007	0.933	0.274	0.601
15 May - 31 May	1.016	0.602	0.553	0.457	0.463	0.496

Table A1.11. Results of tests of goodness of fit to the Single Release Model for release groups of yearling chinook salmon (hatchery and wild) from McNary to Bonneville Dam in 2000.

	Overall		Test 2.C2		Test 3.SR3	
Release	χ^2	P value	χ^2	P value	χ^2	P value
27 Apr - 03 May	1.906	0.386	0.764	0.382	1.142	0.285
04 May - 10 May	0.693	0.707	0.641	0.423	0.052	0.820
11 May - 17 May	4.275	0.118	3.067	0.080	1.208	0.272
18 May - 24 May	0.632	0.729	0.077	0.781	0.555	0.456

Table A1.12. Results of tests of goodness of fit to the Single Release Model for release groups of steelhead (hatchery and wild) from McNary to Bonneville Dam in 2000.

	Overall		Test 2.C2		Test 3.SR3	
Release	χ^2	P value	χ^2	P value	χ^2	P value
20 Apr - 26 Apr	1.120	0.571	0.190	0.663	0.930	0.335
27 Apr - 03 May	1.731	0.421	0.006	0.937	1.725	0.189
04 May - 10 May	1.411	0.494	0.421	0.517	0.990	0.320
11 May - 17 May	0.945	0.624	0.620	0.431	0.325	0.569

Table A.1.13. Results of tests of goodness of fit to the Single Release Model for release groups of yearling chinook salmon (hatchery and wild) from McNary to Bonneville Dam in 1999.

	Overall		Test 2.C2		Test 3.SR3	
Release	χ^2	P value	χ^2	P value	χ^2	P value
20 Apr - 26 Apr	0.750	0.687	0.395	0.530	0.355	0.552
27 Apr - 03 May	1.789	0.409	0.753	0.385	1.035	0.309
04 May - 10 May	4.781	0.092	4.515	0.034	0.266	0.606
11 May - 17 May	7.543	0.023	3.612	0.057	3.931	0.047
18 May - 24 May	6.613	0.037	1.244	0.265	5.369	0.020
25 May - 31 May	0.681	0.711	0.118	0.732	0.563	0.453

Table A.1.14. Results of tests of goodness of fit to the Single Release Model for release groups of steelhead (hatchery and wild) from McNary to Bonneville Dam in 1999.

	Overall		Test 2.C2		Test 3.SR3	
Release	χ^2	P value	χ^2	P value	χ^2	P value
20 Apr - 26 Apr	0.251	0.882	0.120	0.729	0.131	0.718
27 Apr - 03 May	0.358	0.836	0.045	0.832	0.313	0.576
04 May - 10 May	0.033	0.983	0.011	0.917	0.022	0.881
11 May - 17 May	0.942	0.624	0.791	0.374	0.151	0.698
18 May - 24 May	7.552	0.023	5.565	0.018	1.987	0.159
25 May - 31 May	4.118	0.128	0.160	0.689	3.958	0.047

Appendix 2: The relationship between fish length at tagging and detection probability: what are the implications for estimating survival?

Introduction

This analysis was conducted based on the finding of assumption violations as reported in the previous appendix. The assumption violations imply that behavioral heterogeneity existed in some of the release groups. To examine this, we related fish length at tagging to detection probability. We also addressed how the observed behavioral variability affected survival estimates.

Methods

We analyzed release groups of yearling chinook salmon and juvenile steelhead (hatchery and wild combined) at Lower Granite Dam for 2001 (data from this report) and for 2000, since 2001 was such an anomalous year in terms of river conditions. The data correspond to Tables 1 and 6 for chinook and Table 10 and 15 for steelhead in both this report and the 2000 report (Zabel et al. 2001). Although we would have preferred to compare hatchery and wild fish separately, we combined the groups to achieve adequate sample sizes.

These data were analyzed because they corresponded to those presented in the reports. They are not ideal because they represent a heterogeneous group. Some fish were tagged and measured at Lower Granite Dam while others were tagged at traps and hatcheries above the dam. The hatchery fish in particular may have undergone substantial growth after tagging. Thus our methods provide conservative results as a more homogeneous group of fish would likely show enhanced trends.

Splitting the release groups into size classes

The first step was to split the release groups into smaller groups based on length. The goal was to set up a range of size classes while maintaining enough fish in each size class to produce reliable estimates of both detection and survival probabilities. For 2000, we determined that at least 200 fish per size class where necessary. For 2001, which had substantially higher detection rates (due to lack of spill), only 100 fish per group were necessary. To achieve adequate sample sizes while incorporating a range of size classes, the 2000 and 2001 steelhead and the 2000 chinook were divided into 20-mm size-classes. The 2001 chinook were divided into 15-mm size-classes. We note that creating these size classes necessitated eliminating fish that did not fit into size classes with adequate sample sizes. Typically these were the extremely large and small fish and represented a small percentage of the entire sample. Finally, to reasonably assess trends, we required that each weekly release group contained at least 5 size classes; if not, the week was removed from the analysis.

Estimating detection and survival probabilities and regressions analyses

Once the fish were partitioned into size-class groups, we estimated detection probabilities at Little Goose, Lower Monumental and McNary Dams using the standard CJS methods described in the main report. Due to poor survival and resulting small sample sizes, we could not estimate detection probabilities at McNary Dam in 2001 for the steelhead releases. We also estimated survival probabilities from Lower Granite to Little Goose Dam, from Little Goose to Lower Monumental Dam, and from Lower Monumental to McNary Dam. Estimating survival for the last reach was not possible for the 2001 steelhead. After estimating survival and detection probabilities for each group, we regressed the estimates against fish length at tagging to examine for trends.

Estimating survival and detection probabilities with samples stratified by length

We stratified samples to incorporate inherent variability within a release group in a single estimate of detection or survival probability for the whole group (Sandford and Smith 2002). Detection and survival probabilities were estimated for each stratum, as was described in the previous section. We then combined estimates from the strata to yield a single estimate for the whole group. We weighted each stratum by its sample size to generate a weighted average. For example, the stratified survival probability for a single release group was calculated as

$$\hat{S}_s = \frac{1}{N}\sum_{i=1}^{T} n_i \cdot \hat{S}_i$$

where N is the total sample size, i corresponds to an individual stratum, T is the total number of strata, n_i is the sample size of the ith stratum, and $\hat{S}_i$ is the estimated survival probability of the ith stratum. Detection probabilities based on the stratified sample were estimated in a similar manner. These estimated survival and detection probabilities based on stratified samples were then compared directly to estimates based on unstratified samples. We note that the individuals comprising the unstratified groups were slightly different from the release groups from the main report. Since, as described above, fish were eliminated from the stratified groups, these fish were also eliminated from the unstratified groups for consistency. The survival and detection probabilities derived from these unstratified groups were almost identical to those reported in the main report.

Results

There was strong evidence for a negative relationship between detection probability and fish length at tagging for both yearling chinook salmon and juvenile steelhead (Figures A2.1 - A2.8). For the chinook, the trend was particularly apparent at Little Goose Dam, where 3 out of the 4 weekly release groups in 2000 and 2001 demonstrated significant negative relationships ($p < 0.05$, Figures A2.1 and A2.3). The relationship was not as pronounced at Lower Monumental and McNary Dams, but the fewer fish detected at these sites led to more variability about the detection probability estimates and lower power. For the steelhead, significant negative relationships were evident at all dams in 2000 and 2001 (Figures A2.2 and A2.4). In

2000, 7 out of 15 release group/detection site combinations had significant ($p < 0.1$) negative relationships. In 2001, 7 out of 8 groups had significant ($p < 0.1$) negative relationship.

The relationship between survival probability and length was less consistent. For chinook, 1 out of 12 release group detection site combinations had a significant ($p < 0.05$) positive relationship in 2000, while 4 out of 12 combinations had a significant ($p < 0.05$) negative relationship. For steelhead in 2000, while one combination had a significant ($p < 0.1$) positive relationship, 2 out of 12 release group/detection site combinations had a significant ($p < 0.05$) negative relationship. In 2001, 5 out of the 8 combinations had significant ($p < .10$) relationships, but 3 of these were marginally significant ($p > 0.05$). Contrary to expectations, most of the significant relationships involved smaller fish surviving at higher rates than larger fish.

There was close concordance between survival estimates based on the stratified samples and those based on the unstratified samples (Figure A2.9), with all pairs of estimates within 0.02 of each other. There was a slight tendency for higher survival estimates with stratified groups than with the unstratified ones. This indicates that unstratified estimates are likely slightly conservative. The concordance between stratified and unstratified detection probabilities (Figure A2.10) was tighter than that observed for the survival probabilities. Almost all pairs of estimates were within 0.001 of each other.

Discussion

It is clear that behavioral variability within release groups can affect detection and survival probabilities for both yearling chinook salmon and juvenile steelhead. Our main concern is the impact of this behavioral variability on our ability to estimate their survival. While the analyses presented here indicate the effect on overall survival estimates is minimal, several issues merit further consideration. For example, the process of stratifying and recombining has associated variability and potential for bias. Monte Carlo simulations are required to quantify these effects. We plan to address these issues in future reports or publications.

The implications of the results presented here go beyond direct survival of juveniles measured in survival studies. If bypass systems are selective for smaller fish, this may partially explain why multiply-detected fish return as adults at lower rates than undetected or singly-detected fish (Sandford and Smith 2002). Also, transportation studies rely on fish collected in bypass systems. Are these fish qualitatively different from control fish?

The question of why smaller fish were detected at higher rates remains unresolved. Two viable hypotheses are: 1) The fish have different depth preferences as they approach the dam; 2) Larger fish may have greater ability to resist flows into the bypass system. Distinguishing these hypotheses will require further investigations.

A result that was contrary to expectations was that when there was a significant ($p < 0.1$) relationship between survival and length at tagging, in 12 out 14 cases the relationship was negative, meaning smaller fish survived at a higher rate than larger fish. The trend was more pronounced in 2001 compared to 2000. Since there was no spill in 2001 at the Snake River dams, fish that were not detected went through the turbines. Since larger fish had a lower probability of detection, they had a greater propensity to pass the dams via the turbines. Larger fish may have a greater susceptibility to turbine mortality due to a higher strike probability by a turbine blade. In 2000, when spill occurred, the effect was diluted. Finally, avian predators may select larger fish, which could also explain the results we observed.

References

Sandford, B. P., and S. G. Smith. 2002. Estimation of smolt-to-adult return percentages for Snake River Basin anadromous salmonids, 1990-1997. Journal of Agricultural, Biological, and Environmental Statistics 7:243-263.

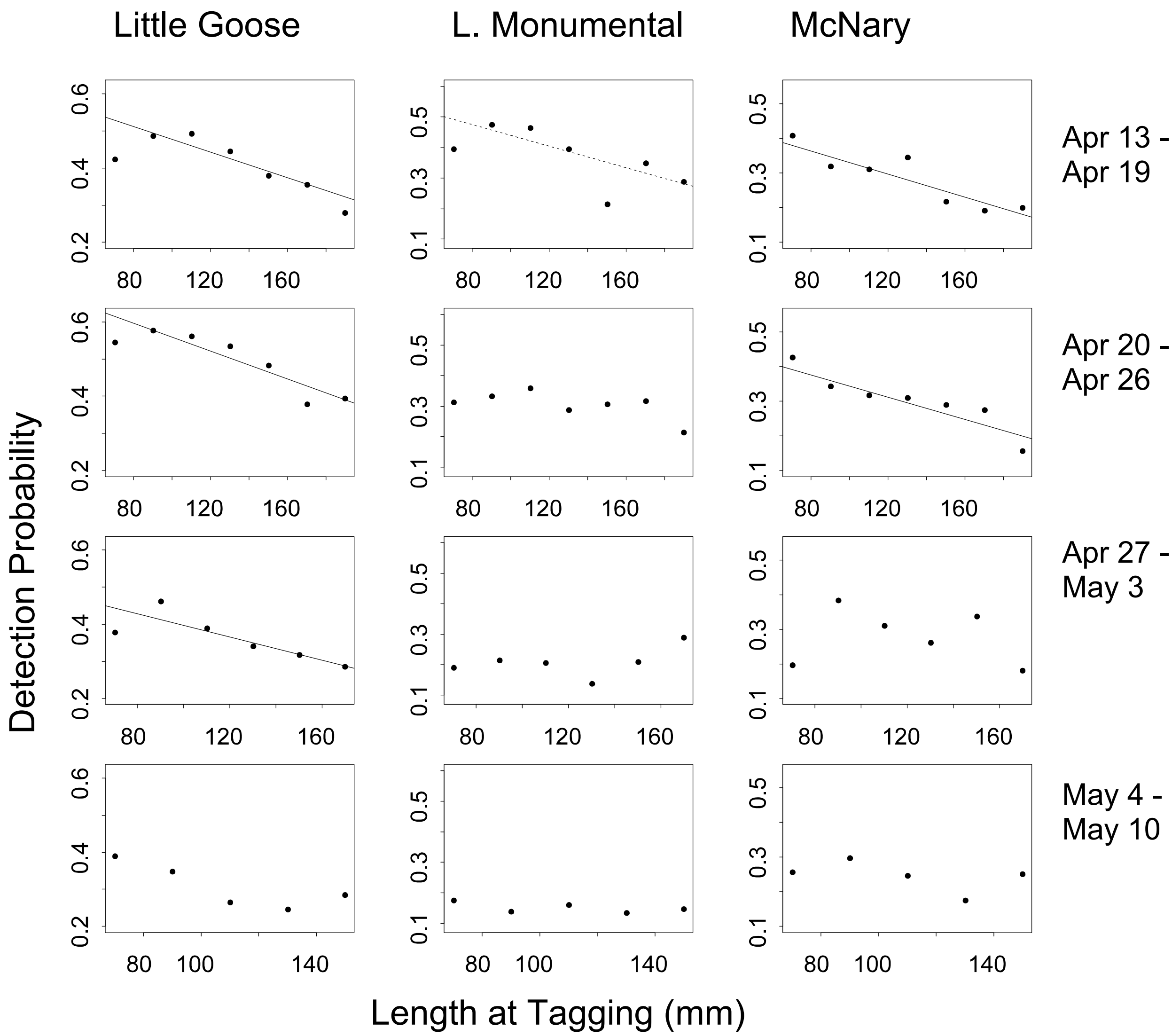


Figure A2.1. Detection probability versus length at tagging for yearling chinook salmon (hatchery and wild combined), 2000. A solid line indicates the regression was significant at the $\alpha = 0.05$ level. A dashed line indicates the regression was significant at the $\alpha = 0.1$ level but not at the $\alpha = 0.05$ level.

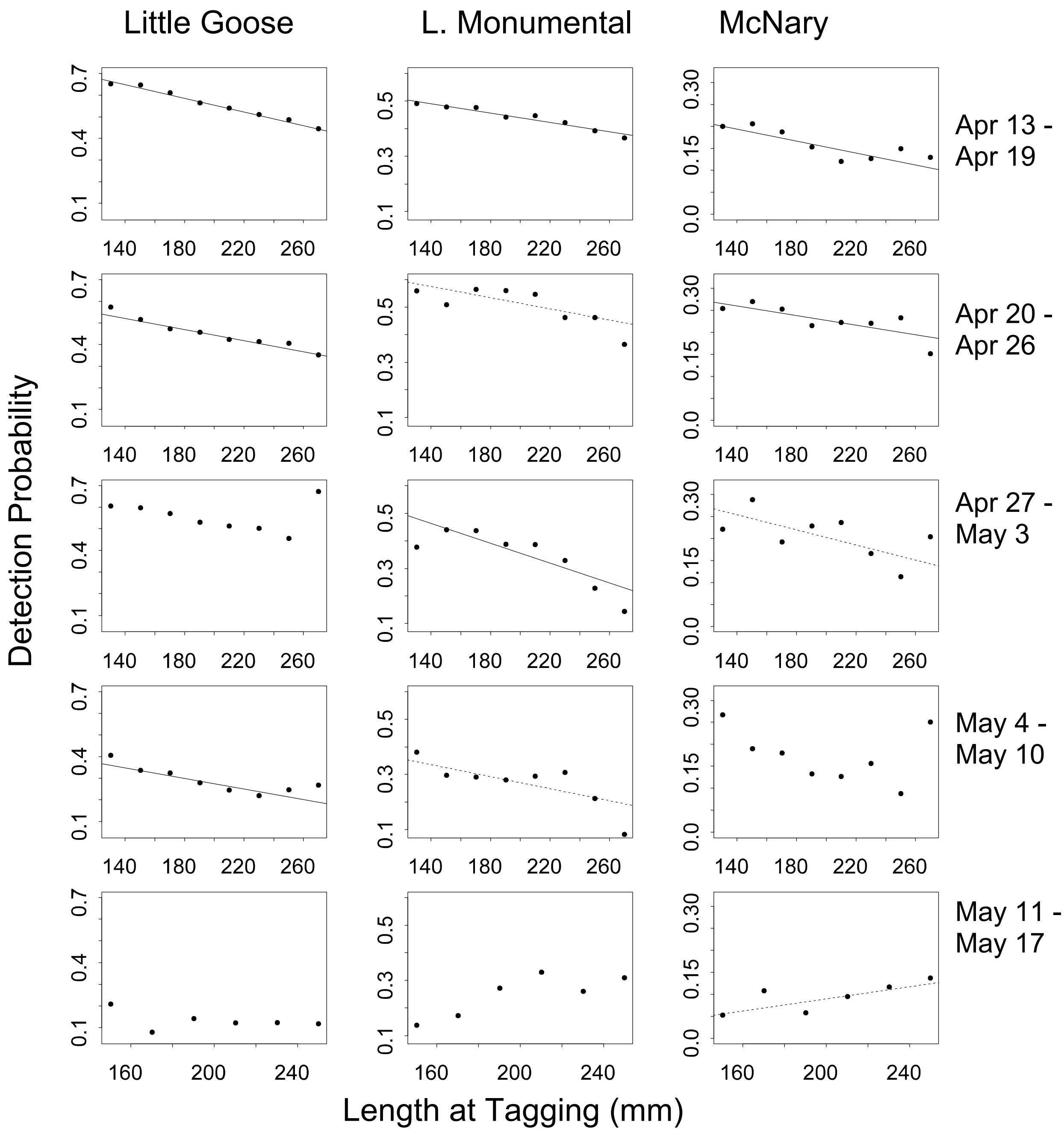


Figure A2.2. Detection probability versus length at tagging for juvenile steelhead (hatchery and wild combined), 2000. A solid line indicates the regression was significant at the $\alpha = 0.05$ level. A dashed line indicates the regression was significant at the $\alpha = 0.1$ level but not at the $\alpha = 0.05$ level.

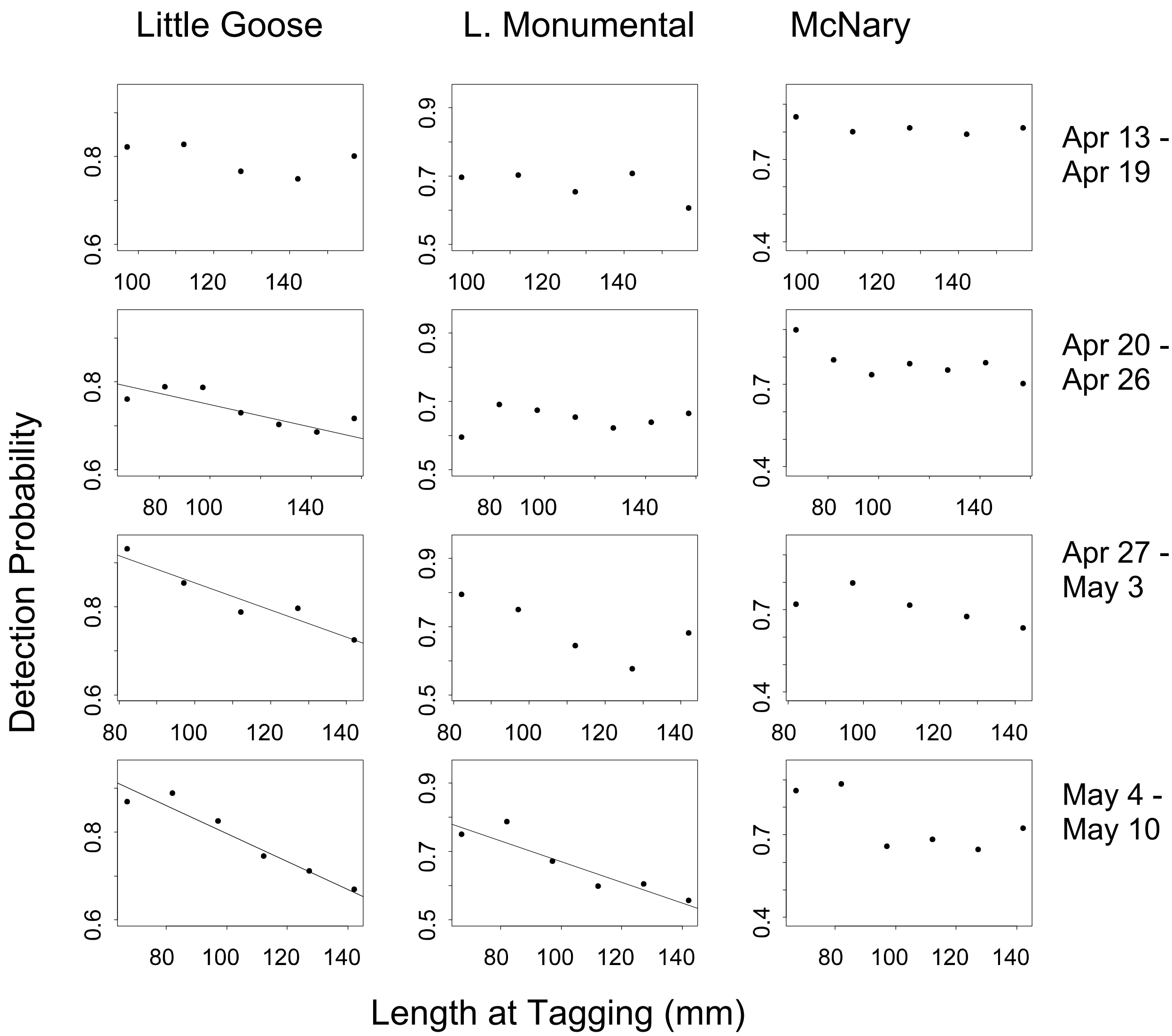


Figure A2.3. Detection probability versus length at tagging for yearling chinook salmon (hatchery and wild combined), 2001. A solid line indicates the regression was significant at the $\alpha = 0.05$ level. A dashed line indicates the regression was significant at the $\alpha = 0.1$ level but not at the $\alpha = 0.05$ level.

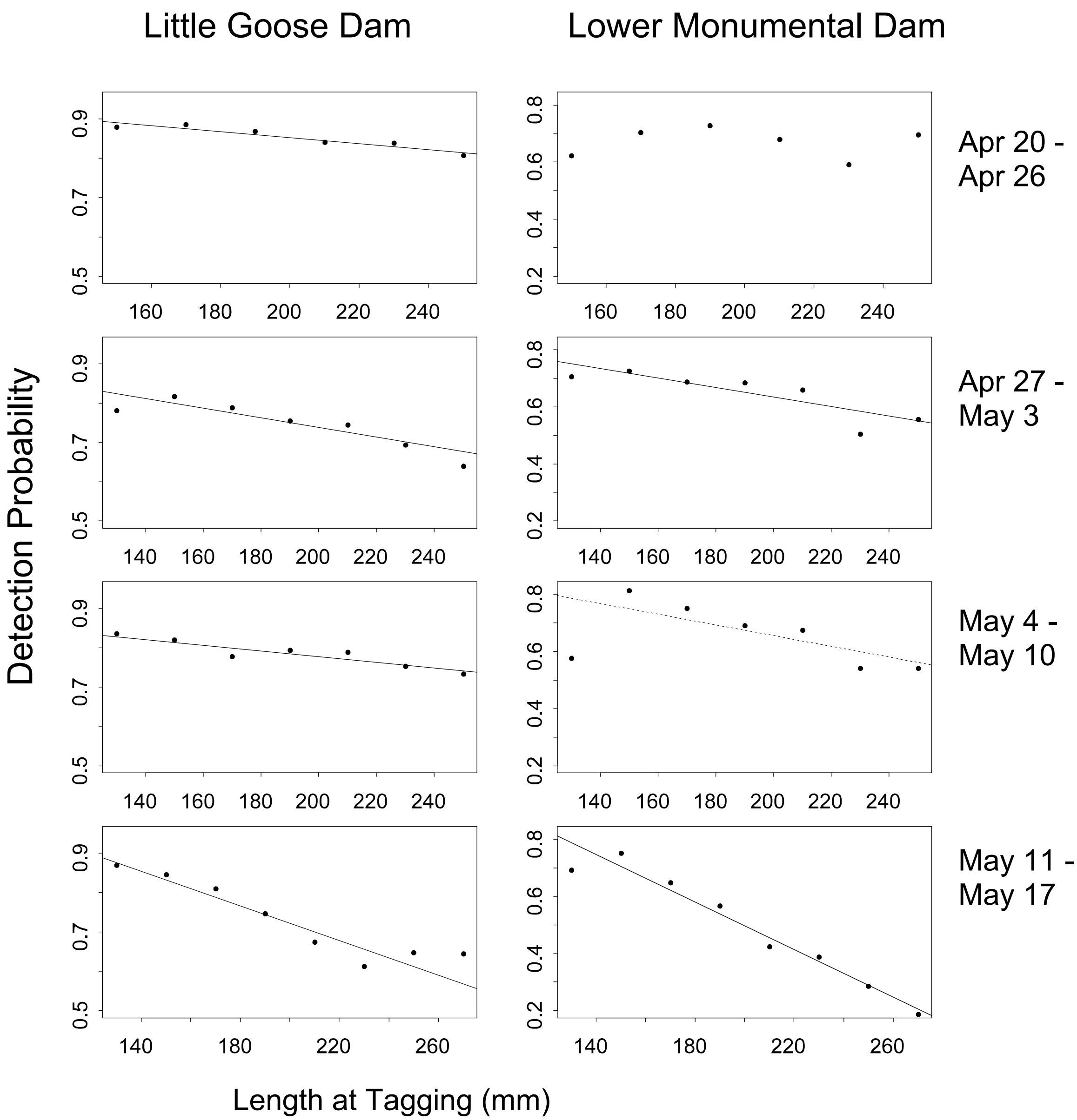


Figure A2.4. Detection probability at Little Goose and Lower Monumental Dams for juvenile steelhead (hatchery and wild) tagged and released at Lower Granite Dam, 2001. A solid line indicates the regression was significant at the $\alpha = 0.05$ level. A dashed line indicates the regression was significant at the $\alpha = 0.1$ level but not at the $\alpha = 0.05$ level.

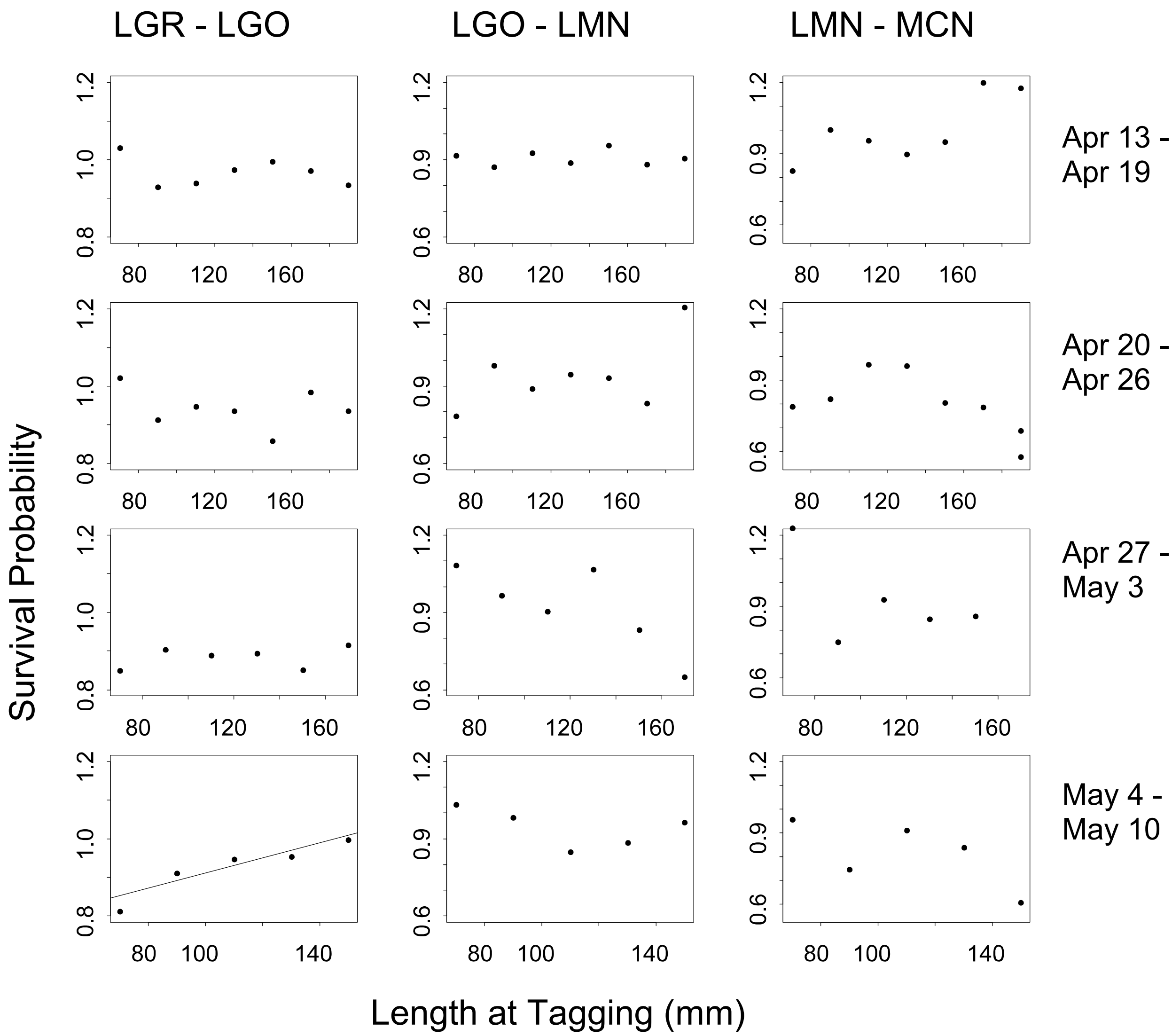


Figure A2.5. Survival probability versus length at tagging for yearling chinook salmon (hatchery and wild combined), 2000. A solid line indicates the regression was significant at the $\alpha = 0.05$ level. A dashed line indicates the regression was significant at the $\alpha = 0.1$ level but not at the $\alpha = 0.05$ level. Abbreviations: LGR - Lower Granite Dam; LGO - Little Goose Dam; LMN - Lower Monumental Dam; MCN - McNary Dam.

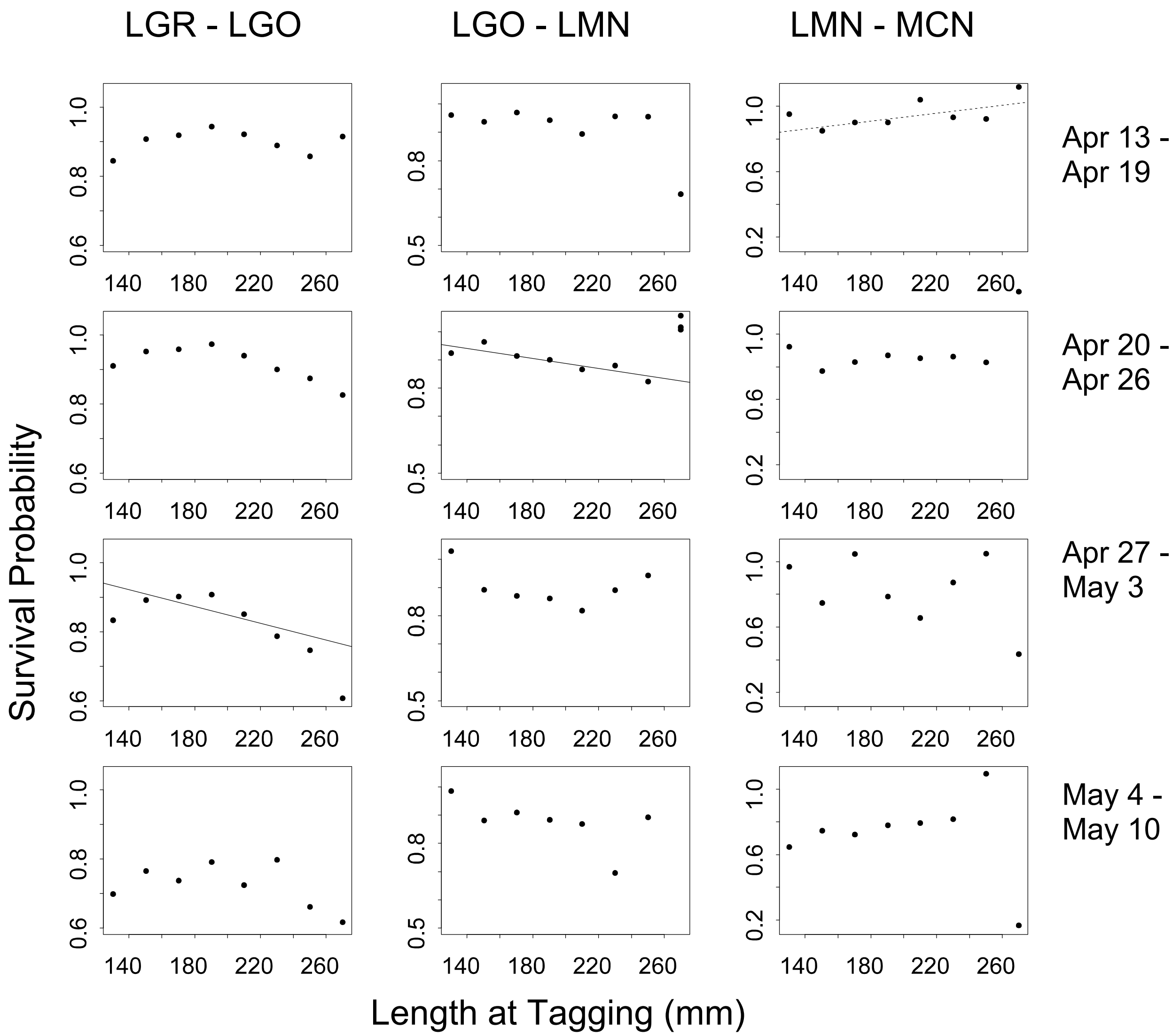


Figure A2.6. Survival probability versus length at tagging for juvenile steelhead (hatchery and wild combined), 2000. A solid line indicates the regression was significant at the $\alpha = 0.05$ level. A dashed line indicates the regression was significant at the $\alpha = 0.1$ level but not at the $\alpha = 0.05$ level. Abbreviations: LGR - Lower Granite Dam; LGO - Little Goose Dam; LMN - Lower Monumental Dam; MCN - McNary Dam.

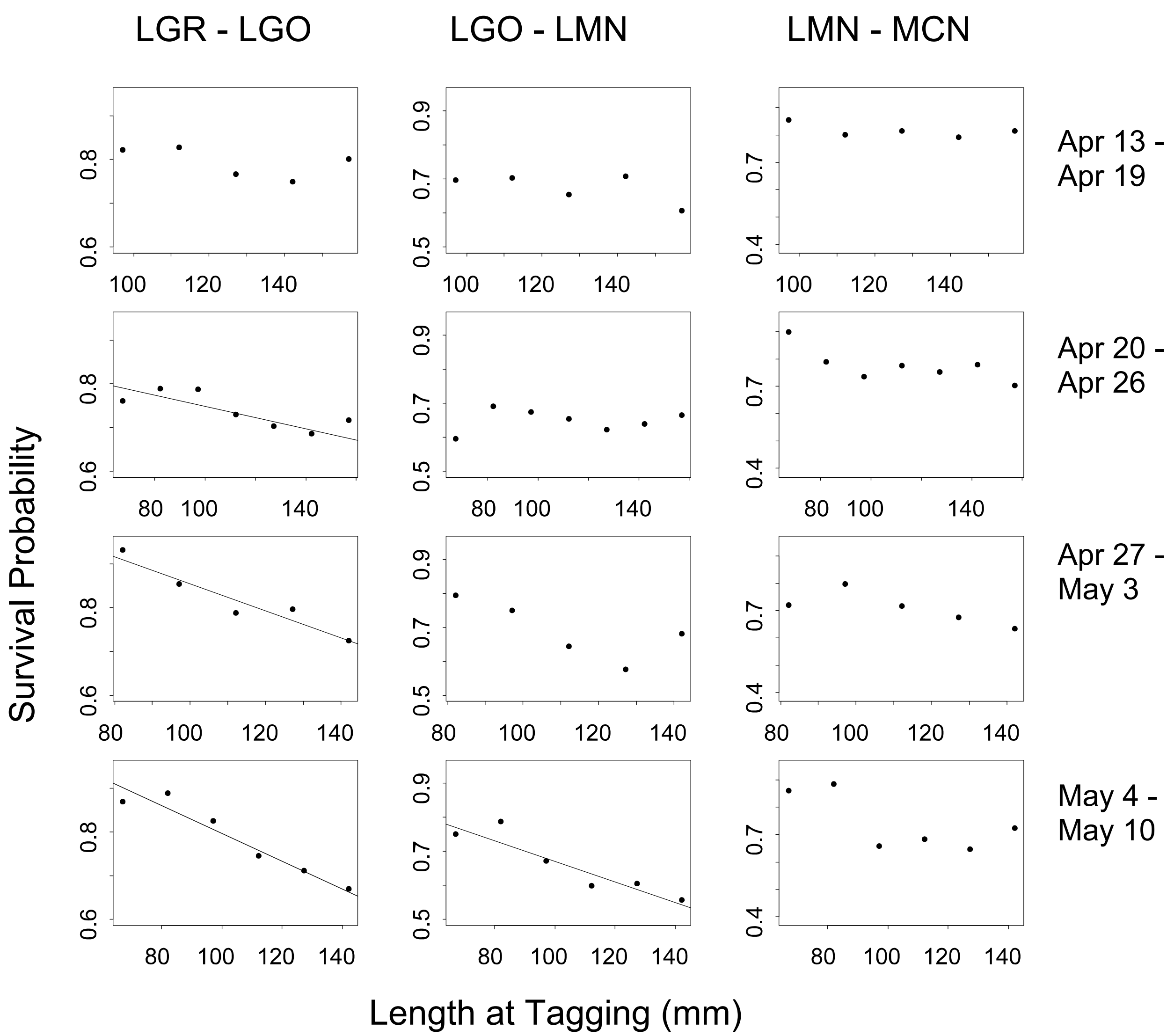


Figure A2.7. Survival probability versus length at tagging for yearling chinook salmon (hatchery and wild combined), 2001. A solid line indicates the regression was significant at the $\alpha = 0.05$ level. A dashed line indicates the regression was significant at the $\alpha = 0.1$ level but not at the $\alpha = 0.05$ level. Abbreviations: LGR - Lower Granite Dam; LGO - Little Goose Dam; LMN - Lower Monumental Dam; MCN - McNary Dam.

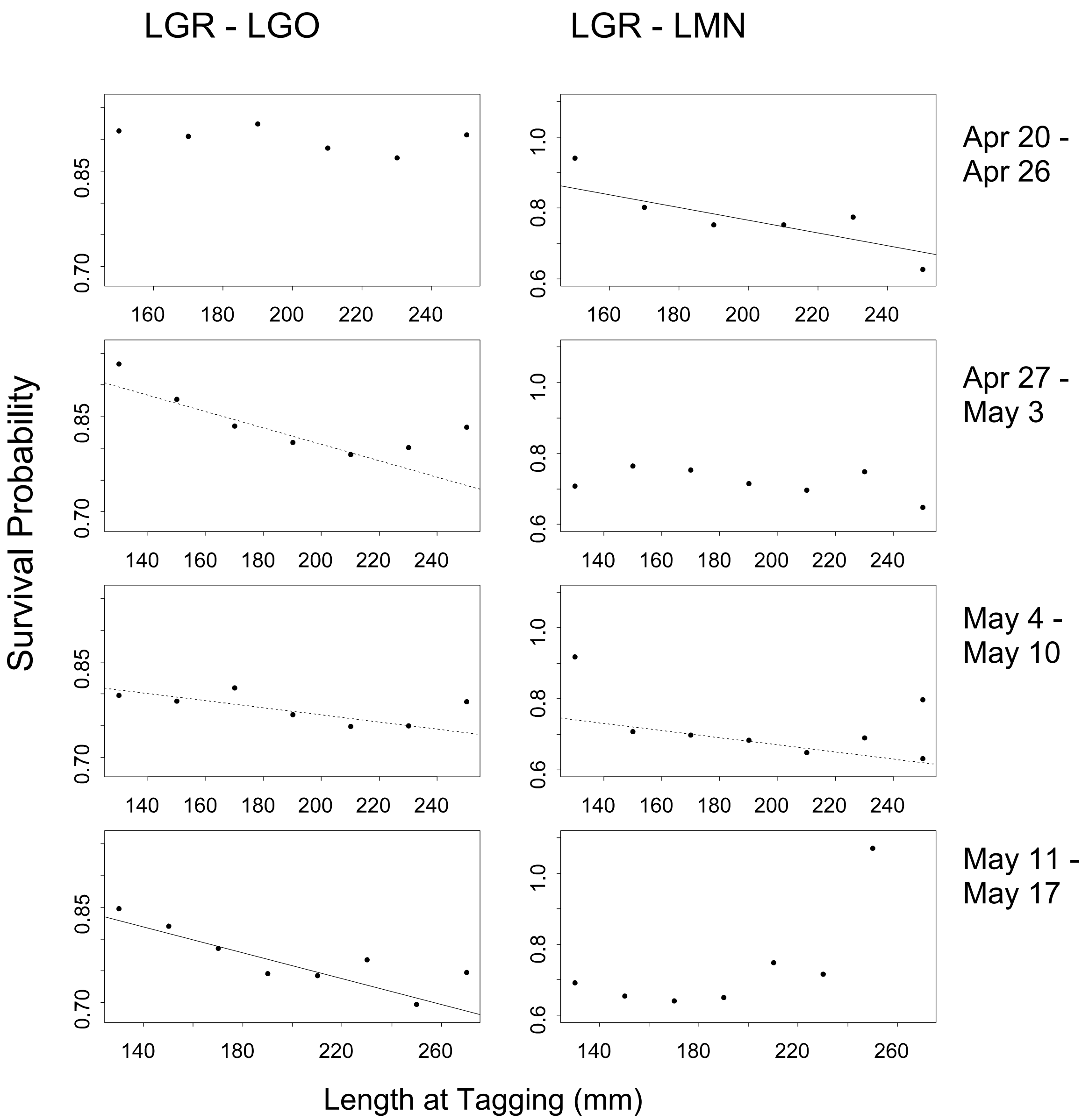


Figure A2.8. Survival probability at Little Goose and Lower Monumental Dams for juvenile steelhead (hatchery and wild) tagged and released at Lower Granite Dam, 2001. A solid line indicates the regression was significant at the $\alpha = 0.05$ level. A dashed line indicates the regression was significant at the $\alpha = 0.1$ level but not at the $\alpha = 0.05$ level. Abbreviations: LGR - Lower Granite Dam; LGO - Little Goose Dam; LMN - Lower Monumental Dam.

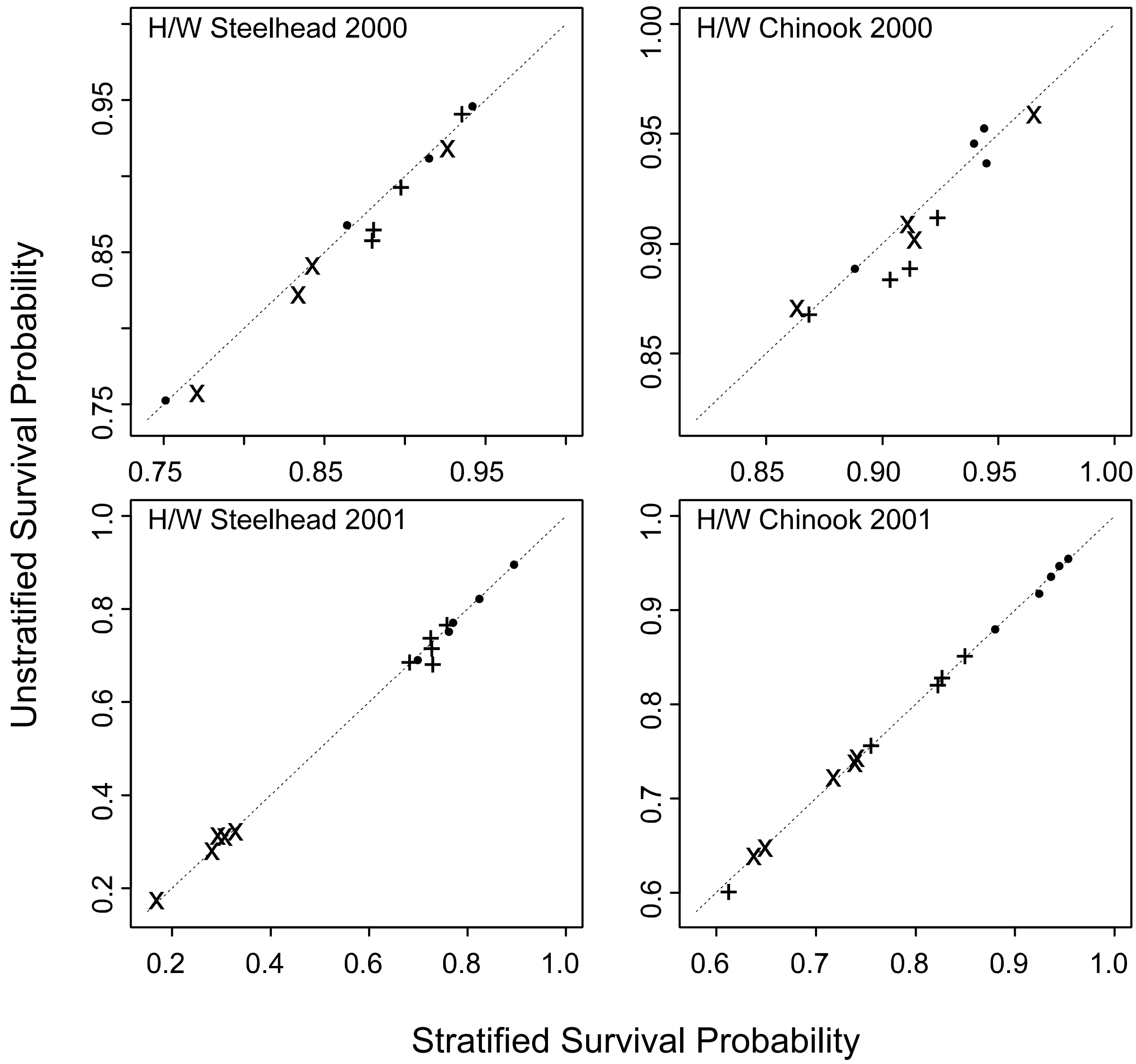


Figure A2.9. Unstratified versus stratified survival probabilities. Symbols: • = Lower Granite to Little Goose Dam; + = Little Goose to Lower Monumental Dam; x = Lower Monumental to McNary Dam.

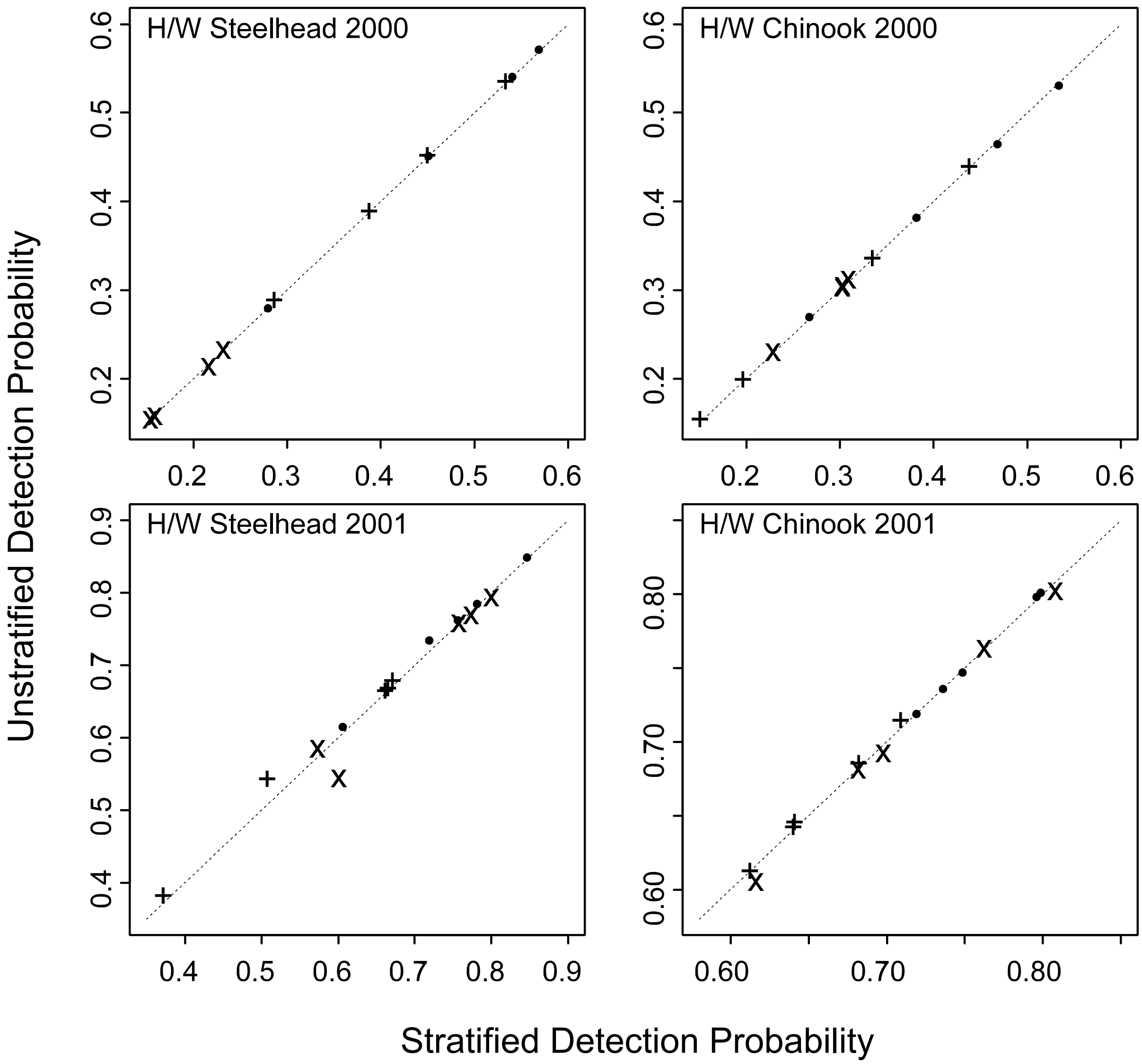


Figure A2.10. Unstratified versus stratified detection probabilities. Symbols: • = Little Goose Dam; + = Lower Monumental Dam; x = McNary Dam.

APPENDIX 3: Comments on the first draft of the report and our response

We received two sets of comments on our first draft of this report. One set of comments was from the Fish Passage Center (FPC), and the other was written by a group of biologists (the joint technical staffs - JTS) from the Columbia River Inter-tribal Fish Commission, Idaho Department of Fish and Game, Oregon Department of Fish and Wildlife, U.S. Fish and Wildlife Service, Washington Department of Fish and Wildlife, and the Confederated Tribes and Bands of the Yakama Nation. We have included and addressed from their letters those comments directly relevant to this report. We did not respond to comments that addressed stylistic concerns or comments that suggested a difference in emphasis of our discussion. Further, we did not include or comment on alternative analyses as they were not peer-reviewed and insufficient methods were included to reproduce them. People interested in the complete comments from these two letters are directed to FPC documents on the Fish Passage Center web site (www.fpc.org).

Based on these comments we: 1) produced Appendix 1 and 2 that address issues concerning assumption testing; 2) modified the experimental design of our analysis of spill effects; 3) deleted plots relating per-project survival to flow indices; and 4) produced this appendix, which addresses specific questions raised in the two sets of comments.

General response to comments on our spill analysis:

Both sets of comments extensively addressed our analysis of the effects of spill. Our main conclusion was (and still is) that patterns of spill during the spring migration period did not result in experimental conditions that allowed for the clear elucidation of the relationship between survival and spill. The primary shortcoming was that the "blocks" (periods of spill and no spill) were too long and could not control for confounding temporal patterns. Even so, when we performed the statistical tests, the results were inconsistent. However, the ability to quantify specific spill benefits is likely feasible with the implementation of a randomized block design with more blocks of shorter duration occurring at several dams.

The conclusion that we were not able to relate patterns of survival with patterns of spill does not indicate that spill has no benefits. We stated several times that spill has potential benefits for migrating juvenile salmon. The role of statistical analyses, though, is to separate subjective beliefs from objective empirical evidence, and that is what we attempted to do in this analysis.

Specific comments:

Orthogonal Contrasts

The FPC comment about the need to use orthogonal contrasts in the statistical analysis of spill effects has merit. We were aware of this issue when we produced the first draft. In fact, we performed the analysis using orthogonal contrasts and the hypothesis tests we utilized in the first draft, and the results were similar. We felt the method we adopted in the first draft was more intuitive, so that is what we presented. With the orthogonal contrasts method, the first hypothesis tested is whether the pre- and post-spill periods had equal survival. If this is rejected, which it was for most cases, then the spill vs. non-spill periods are never compared. We thought this might seem unsatisfactory to some readers. Nonetheless, we decided to adopt the orthogonal contrast method for the final draft since it is statistically valid. Also, if spill is the overriding factor in determining survival, then we would expect equality between the two non-spill periods. If this is not observed, then we can rule out spill as the overriding factor, and there would be no need to compare spill and non-spill periods.

Other experimental design considerations for the spill analysis

Both the FPC and JTS suggested that our choice to segregate stocks and to include a post-spill period reduced the power to detect spill effects. First, we would not consider lumping the yearling fall chinook with the spring/summer chinook since they have different life-history characteristics and higher survival rates. For the final report, we did create a combined spring/summer chinook group for the McNary to John Day Dam reach. This group produced results very similar to those obtained from the Snake River spring/summer chinook.

The statement that survival estimates from the post-spill group are unreliable is unfounded. The survival estimates from this period were precise enough that we had power to detect differences between pre-spill and post-spill blocks in five out the seven tests we performed. As stated in the main report, this result alone demonstrated the existence of temporal trends in survival that were independent of spill effects.

Per-project survival and Survival versus Flow Relationships

We agree with FPC and JTS that presenting mean “per-project” survival estimates when the number of projects varies yearly might produce estimates that are not comparable across years. We removed Figures 12 and 13 from the draft report. However, a suggested alternative method, extrapolation of survival based on yearly estimates of survival per-km, is also problematic. This method ignores the fact that the main source of mortality during downstream migration is dams.

We are currently updating our analysis of the relationship between survival and river flow by incorporating the 2000 and 2001 data. Smith et al. (2002) found no relationship between survival (estimated between Lower Granite and McNary Dams) of Snake River spring/summer chinook salmon and flow exposure during the migration years 1995-1999. The relationship was slightly positive for Snake River steelhead. The addition of 2001, with considerably lower flow rates compared to 1995-1999, may alter these relationships. We will report our results in a forthcoming publication.

We emphasize that river flow varies throughout the migration season and individual fish are only affected by the river conditions they experienced. Using PIT tags, it is possible to track multiple release groups throughout the season and to relate survival to seasonally-varying factors. Using seasonal averages masks some of the complexity of the survival versus flow relationships and does not address the main premise of flow augmentation that increasing flow within a season can increase the survival of fish migrating at that time. This point is illustrated by comparing survival to flow exposure indices (Fig. A3.1). Substantial increases in flow exposure in the middle of the season, for example, did not result in increased survival for either Snake River spring chinook salmon or steelhead.

Reservoir mortality

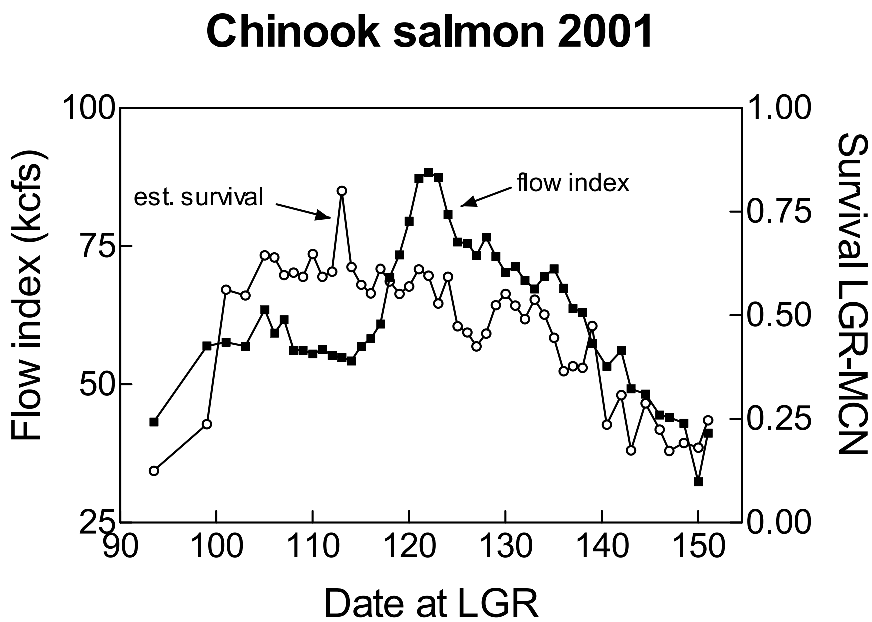
JTS claimed that we erroneously stated in the recommendations section that little mortality occurred in Lower Granite Reservoir, citing Table 26. Table 26 contains detection probabilities, not survival estimates. Survival estimates (Table 25) from Snake Trap through Lower Granite Dam (i.e., containing both the reservoir and the dam) ranged from 0.89-0.96 for hatchery and wild chinook salmon and steelhead. This indicates little mortality occurred in Lower Granite Reservoir. We did modify the recommendation section, though, to point out the extensive mortality suffered in 2001 in the river segment between Lower Monumental and McNary Dams, particularly for steelhead.

Other comments

The FPC stated that no yearling fall chinook were released in the Upper Columbia River in 2001. This is not true. Yearling fall chinook were released at Rock Island and Rocky Reach Dams as part of Chelan PUD survival studies.

Reference

Smith, S.G., W.D. Muir, J.G. Williams and J.R. Skalski. 2002. Factors associated with travel time and survival of migrant yearling chinook salmon and steelhead in the lower Snake River. North American Journal of Fisheries Management 22:385-405.



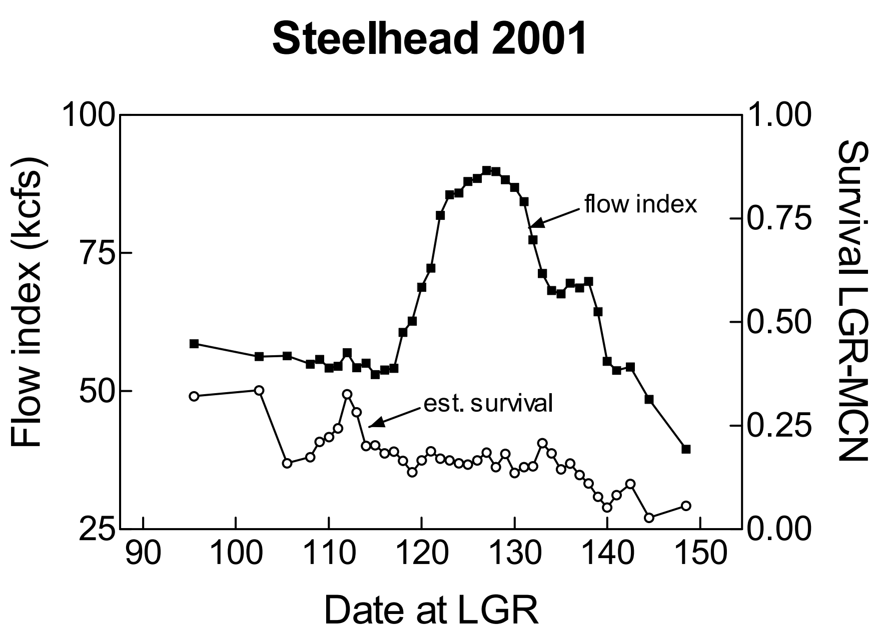


Figure A3.1. Flow exposure and Survival versus day of the year for Snake River spring/summer Chinook and steelhead, 2001. Flow exposure was calculated based on the methods presented by Smith et al. (2002). Survival was estimated from the tailrace of Lower Granite Dam to the tailrace of McNary Dam.

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February 27, 2002

Rich Zabel
National Marine Fisheries Service
7600 Sand Point Way NE
Seattle, Washington 98115-0070

Dear Rich:

The Fish Passage Center (FPC) staff has reviewed the NMFS draft report entitled, "Survival Estimates for the Passage of Spring-Migrating Juvenile Salmonids Through Snake and Columbia River Dams and Reservoirs, 2001". We appreciate your agreement to extend the deadline date for receipt of comments from January 31 to March 1 to allow us to complete our review comments. We offer the following comments for your consideration in completing the final report. We request that, as is required by other Bonneville Power funded studies, that these comments and an explanation of how they were addressed be appended to the final report.

The primary points of our review are summarized below followed by specific discussion.

- We agree with the NMFS overall finding that the lowest survivals and slowest travel times for smolts resulted from the lowest flow and spill that has occurred in recent years.
- The calculated per-project survival estimates are average rates of survival and not appropriate to assess the effect of the flow variable.
- The per-project survival data set is of limited use because each data point is not directly comparable to other data points. Each point represents averages over different reaches and different projects.
- When the calculated average (per project) rate of survival based upon upper reaches is used to extrapolate for survival through lower reaches, the trend is to overestimate survival for the extended length reach.
- The freeze brand data estimates of survival and the recent PIT tag data should not be combined into a single data set and do not support a combined analysis.
- The survival estimation methodology simply produces model-based estimates of survival and collection efficiency, and how various environmental and project operational factors may ultimately influence the "true" survival and collection efficiency being estimated must be investigated indirectly through "correlative" deduction.

- There was a survival benefit to the limited amount of spill for fish passage provided in 2001.
- Increasing flow and spill in past years could account for the temporal increase in survival observed in past years.
- The 2001 data indicates that the temporal trend in survival without spill was downward for both chinook and steelhead throughout the spring migration. This trend indicates that the increases in survival observed at John Day with the implementation of spill were probably due to spill not other temporal effects.

John Day Spill Benefit

NMFS analysis of John Day spill effects in 2001 obscured the benefits of those operations by using narrowly defined statistical tests. In their conclusion to the Annual Report they state that "Thus, the decrease in spill alone may explain much of the lower survival observed for chinook salmon during the 2001 migration." While NMFS states that there may be a detriment to lack of spill in the Snake River, they are extremely reluctant to demonstrate a benefit from spill such as FPC showed for data collected at John Day in 2001.

The FPC analysis of spill uses all the fish detected or released at McNary Dam during specified time intervals related to spill at John Day Dam. The FPC analysis divides the groups into pre-spill and spill groups. NMFS analysis of the benefit of John Day spill is problematic. The NMFS analysis divides the groups into temporal blocks representing pre-spill, spill and post-spill conditions. The greatest differences in survivals were found post-spill when sample sizes were too low for reliable estimates. The post-spill group only represents 8% of the migration based on passage indices at McNary Dam. Therefore, we question the appropriateness of attempting to create a post-spill temporal block for purpose of survival estimation.

Before conducting a series of hypothesis tests, NMFS split the yearling spring/summer chinook data into four distinct groups by regional stock designations. These groups included Snake River spring/summer stocks, Yakima spring stocks, Upper Columbia spring stocks, and Upper Columbia summer stocks (although they show the latter group having yearling fall chinook also, but no yearling fall fish were released in the Upper Columbia River in 2001). Survival estimates from McNary Dam tailrace to John Day Dam tailrace were obtained for each regional stock group separately for three temporal periods, pre-spill, spill, and post-spill. NMFS observed a pattern of the highest survival estimates during the spill period, followed by lower survival in the pre-spill and the lowest survival in the post-spill period. This same pattern occurred across the four regional stock groups. This similarity in pattern across groups supports the FPC's use of an aggregate of all yearling chinook detected at McNary Dam in their estimation of reach survival from McNary Dam tailrace to John Day Dam tailrace in 2001. NMFS conducted their analysis only at the level of the individual regional stock groups, but given the common pattern across groups, it would be beneficial for NMFS to also conduct their analysis at the level of the combined stock aggregation. This would increase sample sizes, reduce variances within blocks, and thereby improve our power of detecting significant differences among temporal periods if they do exist within the underlying data.

In conducting their hypothesis tests, NMFS utilizes the capabilities of the SURPH computer software to compute likelihood ratio tests between a model and a simpler (parameter reduced) version of that model. For example, the "full" model would allow for a different parameter of survival in each temporal block, whereas a "reduced" model could assume a common survival across the three blocks, and thereby a single survival parameter. Let the subscript j denote the temporal block, where 1 = pre-spill, 2 = spill, and 3 = post-spill. This gives a null hypothesis of $S_1 = S_2 = S_3 = S$ and alternative hypothesis of S_j's not all equal. This is what NMFS is testing in their Hypothesis H_{10} although they label the null hypothesis as $S_{spill} = S_{no\text{-}spill}$. In the second hypothesis, NMFS is testing a null hypothesis of $S_1 = S_3$ versus the alternative hypothesis of $S_1 \neq S_3$. If we put this in the context of an experimental design, we would have for a given regional stock group with three temporal periods, a main effects test of "between periods" with 2 degrees of freedom. If we split these 2 degrees of freedom into a pair of orthogonal contrasts, we would have for the first contrast the test of spill versus average of no-spill, *i.e.*, $S_2 = ½(S_1 + S_3)$, and for the second contrast the test of pre-spill versus post-spill, *i.e.*, $S_1 = S_3$. This is the proper set-up for orthogonal contrasts. It appears that NMFS is attempting to perform a similar set of orthogonal contrasts through the use of the SURPH program. However, the first hypothesis being tested by NMFS is simply the main effects test of "between periods." In this situation, the second hypothesis is not an orthogonal contrast relative to the first hypothesis. NMFS could have just as easily run the null hypothesis of $S_1 = S_2$ and $S_2 = S_3$ against each of their respective alternatives, which is akin to inspecting all differences between pairs of means, rather than running a set of planned comparisons. With the planned comparison, only the first orthogonal contrast is really of interest regarding the statistical significance of survival in Period 2 versus the other two periods. With the approach used by NMFS, the two sets of hypothesis still do not address the question of statistical significance of survival in Period 2 versus the other two periods, rather the *a-posteriori* comparisons of mean survivals between each pair of periods is more appropriate.

NMFS inappropriately concluded that their hypothesis testing showed that no statistical significance could be ascribed to the estimated higher survival of Period 2 (spill period). However, the survival estimates obtained by NMFS for Period 2 were consistently higher across the four regional stocks in 2001, and across the recent past years. If NMFS had directly tested the periods of pre-spill vs spill and spill vs post-spill, they would have come to a different conclusion. This test would have been accomplished in SURPH as the likelihood ratio test of "reduced" model divided by "full" model for each pair of periods being compared (*e.g.*, null hypothesis of $S_1 = S_2$ versus alternative hypothesis of $S_1 \neq S_2$ and null hypothesis of $S_2 = S_3$ versus alternative hypothesis of $S_2 \neq S_3$). In these test, all that will result is that Period 2 survivals were greater than either Period 1 or Period 3 survivals. One still has to make the inference to what mechanism was contributing to the higher survival in Period 2. We contend that when one looks at 2001 and the other recent years that there is a clear link to higher spill volumes occurring during Period 2 in each year, so even in years where the proportion of spill doesn't change much, the typical increasing flows in the latter half of May will result in increased volume of water spilled. During these periods of increased flows, the turbidity level of the water also increases, and the duration of passage of fish through the reservoirs decreases, thus contributing to lower predation levels. It is the combination of all these factors that influences the improved survival observed in each year during Period 2. But in 2001, with constantly low flows, very clear water, and slow travel time from McNary Dam tailrace to John Day Dam tailrace, it is the presence versus absence of spill at John Day Dam that occurred between periods. From this set of circumstances, it appears that a link to spill improving survival can be made. Otherwise, one could argue that because we can only make "correlative," not "causative" comparison between smolt survival levels and associated environmental and project operational factors in the hydro system, we in essence should abandon the futile endeavor of analyzing reach survival estimates against these factors.

NMFS recognizes that there is a measurable change in collection efficiency at John Day Dam after the initiation of spill. However, NMFS does not relate this change to a change in survival nor to the operations at the project. Given that nearly every study NMFS conducted shows spill has a significantly lower rate of mortality than any other passage route, it seems this alone could be used to biologically explain the change in the survival estimate observed. At the very least it demonstrates an alternate hypothesis that questions the "temporal trend" theory as the explanation.

McNary Dam Spill Benefit Analysis

There was very limited spill at McNary Dam in 2001. Spill occurred every other day and was limited to an instantaneous average of 30 kcfs. NMFS found no survival benefit to spill at McNary in 2001. In fact they found survival significantly lower during spill than pre-spill. It is likely that the extremely low spill levels resulted in a negligible spill benefit at McNary this season. The detection efficiency for yearling chinook at McNary did not change appreciably between mid-May prior to spill and through the spill period. This suggests that spill did not improve overall fish passage efficiency enough, (especially when occurring every other day) to improve passage conditions at McNary Dam. Also, the survivals for the reach LGR to MCN showed a downward trend throughout the season, so that NMFS finding a lower survival during spill which was toward the end of period for which they could estimate survivals is consistent with that seasonal trend, and probably was not related to spill.

Reach and System Survival

NMFS uses per project survival plotted against a flow index as a means of comparing annual system survival to flow conditions (Figure 13 page 91 Annual Report). They regressed per project survival by flow index and found no significant relation. However, this type of plot and analysis may be very misleading. Annual per project values are derived from differing length reaches in different years. For example, yearling chinook data incorporates one project (LGR to LGS) in 1993, two projects (LGR to LMN) in 1994, four projects (LGR to MCN) in 1995 through 1998, and eight projects (LGR down to BON) from 1999 to 2001.

Using short reach estimates to characterize a season can significantly misrepresent what occurs over the longer reach. For example, if we used the 2001 LGR to LGS reach survival (0.939) for yearling chinook to represent 2001 survival (as NMFS used for 1993 in figure 13 page 91 Annual Report), then 2001 would appear as a very favorable migration year. Expanding this 'per project' survival to a system survival for 2001 would yield 0.68 LGR to BON survival for yearling chinook. This is nearly three times the NMFS reported survival of 0.27 for this reach. The same holds true for LGR to LMN survivals (as NMFS used to represent 1994 in Figure 13). If the 2001 LGR to LMN survival was averaged per project it would yield a per project survival of 0.877. Expanding this to the LGR to BON reach would yield a system survival of 0.45. Nearly twice as high as the NMFS 2001 estimate. A final example, using 2001 steelhead survival for LGR to LGS (0.801) and expanding this to a system survival would yield 0.26. Comparing the resulting value to NMFS reported system survival of 0.04 shows how misrepresentative the expansion of short reach survivals can be for characterizing an entire season.

As the above comparison shows the assumption that per project survival is constant throughout the system oversimplifies both the biology of migrant fish and the physical characteristics of the hydrosystem. Juvenile salmon migrating in-river would be expected to show increasing mortality over time in a year like 2001, when no spill occurred in the Snake River forcing migrant population to pass through multiple dams via turbines or bypasses. Also, comparing survival over short reaches in the Snake River (LGR to LGS or LGR to LMN) to longer reaches (LGR to MCN) could fail to capture the differences between these very different sections of river.

The freeze brand survival estimates from the 1970's should not be directly compared with the 1990's PIT-tag estimates without a great deal of caution. These data were collected in a very different fashion and likely the precision of the freeze brand estimates would be much lower. It is possible that the magnitude of low survivals during the 1970's is meaningful to compare, however, plotting both types of data in the same graph gives the impression that these are comparable data sets. Clearly, this is not the case.

NMFS found no significant relationship between flow and survival when they regressed their flow index versus seasonal per project survival. But the per project survival rate compresses data points between 0.9 and 0.98. This probably makes it very difficult to find any significant relationship from this sort of presentation of the data.

NMFS presents a relatively short-time series of survival vs. flow data (1993-2001). With the exception of 1994 and 2001 the average flow exceeded the Biological Opinion flow targets. The Biological Opinion flow targets were specifically chosen based on data that showed little change in survival with flow above the targets. Consequently, rather than showing a no flow/survival relation, the data are validating those upon which the flow targets were based.

CONCLUSIONS

- All of the data collected in 2001 validates the need for and the benefits of implementation of the biological opinion flow and spill measures even in low run-off years. The preponderance of data indicates that the low flow and low spill levels resulted in extremely poor migration conditions and very poor survivals.

- NMFS inability to reach a definitive conclusion regarding the benefits of spill in 2001 is the result of their chosen statistical approach. Their own data shows an increase in survival with spill in 2001, NMFS chose not to discuss or address this point. NMFS ignored or neglected to address other tests, which indicate a benefit of spill. NMFS analysis does not disprove the conclusion that spill at John Day was beneficial.
- The NMFS “per-project survival approach” to evaluate the effect of flow and spill across years is not valid. It clearly overestimates survival. In addition historical freeze brand data is not directly comparable to present PIT tag data.
- NMFS own survival estimates show that survival was lower in 2001 than all recent years that PIT tag data is available.
- The survival estimation methodology does not allow the incremental allocation of survival to specific environmental variables.

Sincerely,

Michele DeHart

Michele DeHart
Fish Passage Center Manager

Joint Technical Staff Memorandum

CRITFC IDFG ODFW USFWS WDFW

March 19, 2002

Mr. Rich Zabel
National Marine Fisheries Service
7600 Sand Point Way N.E.
Seattle, Washington 98115-0070

Dear Mr. Zabel:

The Columbia River Inter-Tribal Fish Commission, Idaho Department of Fish and Game, Oregon Department of Fish and Wildlife, U. S. Fish and Wildlife Service, and Washington Department of Fish and Wildlife are submitting the following comments on the National Marine Fisheries Service (NMFS) draft report entitled, "Survival Estimates for the Passage of Spring Migrating Juvenile Salmonids Through Snake and Columbia River Dams and Reservoirs, 2001" (Zabel et al. 2001). We have reviewed and concur with comments submitted by the Fish Passage Center (FPC) dated February 27, 2002. We are requesting that both sets of comments be appended to your final report along with a response explaining how the comments were addressed.

General Comments

The report draws conclusions about the benefits of spill and flow augmentation that could be easily misinterpreted without additional explanation. Readers unfamiliar with the data and methodologies could be mislead without further discussion of limitations of the data and other caveats regarding the analyses. A majority of our comments relate to this point. Additional explanation and qualification of statements will serve to diffuse ongoing regional controversies related to flow and spill mitigation measures.

Many of the statements in the draft appear to contradict each other. As an example, the report states that the benefits of spill are inconclusive, but in other parts of the report spill is recognized as beneficial and an important recovery measure. Additional explanation would clarify findings and would reduce these apparent contradictions.

Several Figures are almost impossible to interpret because they are too "data heavy". For example, note Figures 2 and 10. We suggest that the data be divided into two or three graphs.

The report needs to note the limitations of reach survival estimates. The fact that they have limited utility with respect to evaluating indirect and delayed mortality should be described in the text and in the final recommendation/conclusion section of the report.

While the report offers a gross description of operational and environmental conditions present during the survival studies, the report should direct the reader to specific data, reports or information where these conditions are better described.

While we agree that it is important to continue to obtain new information about direct juvenile salmon survival under recent operations and system configuration, we also believe that past data is important to consider for current management decisions. Past survival studies provide valuable information as to trends in survival and productivity that should be considered with more recent information.

With respect to the recommendations section, which really contains study conclusions and should be labeled as such, we find that some of the conclusions do not comport with the data and survival estimates contained in the report. This is a considerable problem. For example, conclusion/recommendation #4 states that "…[l]little mortality has been found in Lower Granite and other reservoirs". This statement is not correct when survival of individual release groups is considered. For example, the Lower Granite reservoir survival estimates presented in Table 26 indicate that hatchery chinook suffer about 11% mortality through Lower Granite reservoir. Further, even the pooled group survival estimates in Table 11 indicate that the McNary Dam to John Day Dam steelhead mortality was almost 15% - a very high rate compared to other reservoir survival estimates. Generalized conclusions of the data and analysis in the report that does not present the variability of the ranges of estimated salmon survivals is problematic for readers that do not have the background or time to consider the contents in the full report and creates a false impression with respect the actual results of the study.

A key issue not addressed in the conclusion and recommendations section is what are the critical study design assumptions and whether or not these assumptions (see Chapter Six in Burnham et al. 1987) in the study design have been met. Earlier in the report it is stated that generally the assumptions were met but how each one was met was not explicitly described in the report. This should be remedied for the final report.

Specific Comments

Benefits of Spill

Benefits of limited spill, which occurred in 2001, are evaluated. The survival estimates included in Table 40 of the draft report, show an increase in survival with spill, although NMFS concludes as a result of their statistical tests that demonstrating in-season effects of spill is "problematic." NMFS appropriately qualifies this conclusion by stating that a lack of relationship may have been due to less than an ideal experimental design and low spill provided in 2001 compared to past years and that spill provides additional (travel time) benefits that are not realized until later in the life cycle. NMFS needs to further qualify its' findings with a discussion of the limitations of their analysis including effects of small sample sizes caused by segregating releases into four release groups (Snake River spring/summer chinook, Yakima spring chinook, Upper Columbia spring chinook, and Upper Columbia summer chinook) and into three blocks (pre-spill, spill, post-spill). The lack of a statistical difference in survival between the release groups and blocks was driven primarily by low sample sizes in the post-spill groups.

The report also states that the observed increase in survival in 2001 may have been due to temporal effects that have been observed in previous years. However, unlike past years, spill was the only environmental variable that had increased when the temporal increase in survival was observed. In 2001, flows, and turbidity, between McNary and John Day dams were consistently low throughout the migration season and travel times were long. In addition, although sample sizes were too low for statistical tests, unlike past years, fish survival estimates were more precise and decreased dramatically for groups released on or after June 7 that occurred coincidental with termination of spill. These observations and further discussion needs to be included in the report to avoid misinterpretation of results and conclusions related to the benefits of spill on fish survival.

Flow/Survival Relationships

The report concludes that due to low flow and spill conditions in the Snake and Columbia Rivers in 2001, system (Lower Granite to Bonneville) survivals of chinook and steelhead were extremely low. Chinook system survival in 2001 was 27.6% and 4.2% for steelhead, which was considerably lower than any recent years. Similar findings were reported for survivals calculated on an average per-project basis. To determine the effect of flow on survival, NMFS conducted regressions between per-project survivals dating back to the 1970's and flow. NMFS relies on regressions of per-project survivals and flow to explore the relationship between flow and survival. NMFS does not detect a relationship with this analysis because of the variables they selected to represent fish survival. Per-project survival when extrapolated from short reach estimates, does not accurately reflect fish survival through the whole hydrosystem, overestimating survival and obscuring a flow survival relationship. It is difficult to detect statistically a flow-survival relationship using historic per-project survivals because the yearly survivals were based on different tagging methodologies (early years were based on freeze brands and recent data based on PIT tags) and different number of projects used in average per-project survival estimates (range of 2-7 projects). Using historic per-project survivals tends to reduce the variability in survivals between years (ex: excluding steelhead survival in 2001, survivals for chinook and steelhead ranged from 0.85 to 0.95 during 1993-2001) and reduce the ability to detect a flow-survival relationship.

To conclude, we hope that these comments will be considered and reflected in the drafting of the final report. The report provides important information for Columbia River fish passage management decisions. Improving the analyses, and strengthening the discussion, and providing appropriate conclusions with caveats to better explain the strengths and weaknesses of the data and analyses will better inform fishery managers and the region how to best design and implement fish passage measures to maximize survival of spring migrating fish.

Sincerely

Earl Weber
Columbia River Inter-tribal Fish Commission

Ron Boyce
Oregon Department of Fish and Wildlife

Shane Scott
Washington Department of Fish and Wildlife

Steve Pettit
Idaho Department of Fish and Game

Dave Wills
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